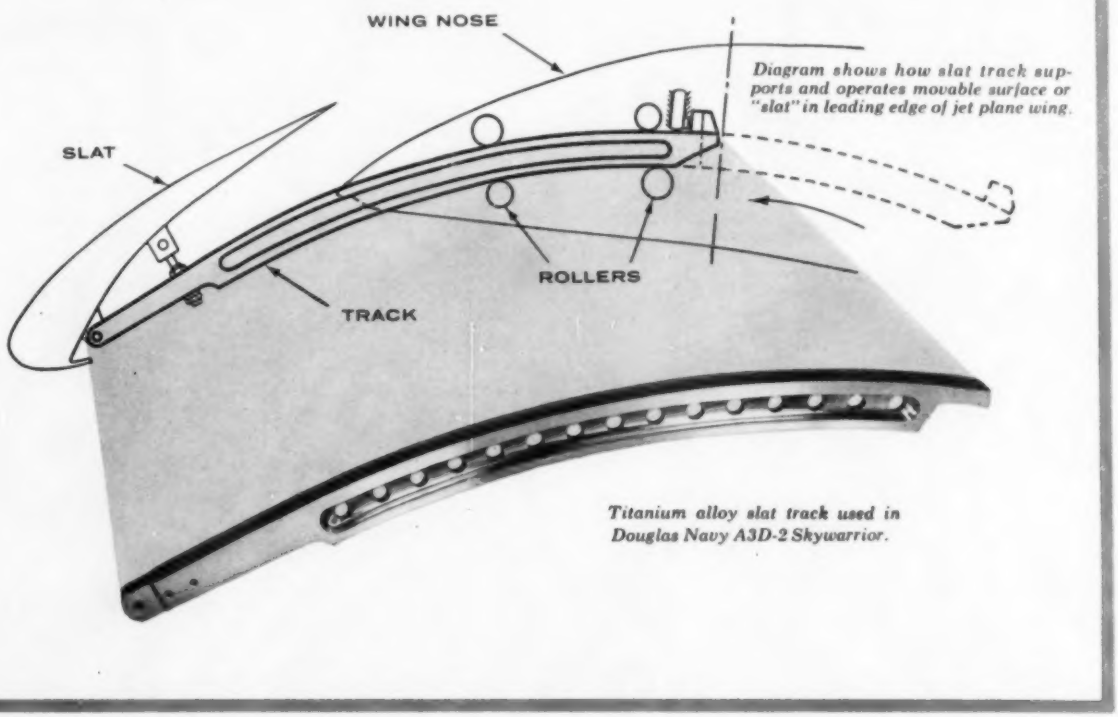
metal progress

september 1958


WING NOSE
SLAT
TRACK
ROLLERS
Diagram shows how slat track supports and operates movable surface or "slat" in leading edge of jet plane wing.
Titanium alloy slat track used in Douglas Navy A3D-2 Skywarrior.

How Douglas Aircraft used Titanium to gain

44% WEIGHT SAVING...IMPROVED PERFORMANCE

Douglas engineers faced numerous problems in designing the Douglas A3D-2 Skywarrior slat tracks. Among these were problems of weight reduction, high inertia forces, corrosion and compass deflection.

The application called for a metal with high strength-to-weight ratio, superior corrosion resistance, and non-magnetic properties. Engineering evaluation pointed to heat-treated 6Al-4V titanium alloy as being most suitable for this application.

In subsequent tests, the heat-treated titanium alloy proved out with the following outstanding results:

1. *Weight savings of 44% were obtained, as against any other suitable materials.*
2. *Plating problems encountered with steel tracks were eliminated.*
3. *Titanium's non-magnetic properties minimize compass deviation.*
4. *Repeated impact loads against the stop (20,000 cycles) caused no cracks or failures of any kind.*

DESIGN REQUIREMENTS AND PROPERTIES OF 6Al-4V TITANIUM

Property	Douglas Min Design Requirements	Average Test Results (formed and heat treated)
Ultimate Strength, psi	150,000	150-159,000
Yield Strength (0.2% Offset), psi	135,000	136-146,000
Elongation (in 4D), %	8	13
Reduction of Area, %	20	40-43
Rockwell C Hardness (max)	42	—

Are *you* making full use of titanium and its alloys in designing for lighter weight, improved performance? Our experienced Service Engineering group is ready to assist you now.

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Metal Progress

September 1958 . . . Volume 74, No. 3

Stylized Staircase, by GEORGE KARMAN, won second prize in the 1958 *Metal Progress* Cover Competition at Cleveland Institute of Art.

Feature on Steelmaking

Modern Attacks on Iron Ores, by C. F. Hoffman 67

While direct reduction will be applied commercially in some locations, it will not supplant the blast furnace, which is one of the most efficient metallurgical tools in use. To meet the increased future needs for more iron, steel mills will strive for higher production from existing furnaces by means of technological improvements. It has been estimated that, with beneficiated raw materials and with newly developed uses of oxygen and other techniques, production in the same size blast furnace used in 1940 can be increased 67%. (D1, D8, B16; Fe)*

Forging Blooms From Ingots, by John E. Decker 71

A short, heavily tapered ingot is forged after the piped zone is isolated from the sound steel by a punch. Tests show the blooms to be sound and free from segregation. (F22, D9k; ST, 4-52, 5-59)

Sintering: 5000 Tons a Day, Staff Report 74

United States Steel's new sintering plant is virtually automatic in operation. The strong porous cake provides a more effective blast furnace burden. Furthermore, the ore supply is indirectly increased because fines formerly lost are used. (B16a, D1; Fe)

Engineering Articles

Mechanized Austempering of Steel Harrow Disks 78

Parts are heated at 1575° F. in a neutral salt bath for 1.6 min., then austempered at 750° F. in a nitrate salt for 6 min. The bainitic structure obtained prevents directional cracking. (J26p, 18-74; ST)

Many Metallurgists Still Needed 80A

Tells what a metallurgist is and does, the necessary preparation and qualifications, opportunities, salaries, future progress. (A3)

Foil Clad Laminates in Printed Circuitry, by D. K. Rider 81

Start with an insulating base, glue on very thin copper foil (free of holes or inclusions), etch away unwanted areas leaving behind conductive paths from point to point. This concept leads to rugged assemblies, mass-produced at minimum cost. (T1c; Cu, 4-56)

Case History on Induction Hardening Large Drive Gear, by Victor H. Pagano and Charles J. Kropf 86

Changing from carburizing to induction hardening permitted the use of less costly steels, and saved 5 lb. of nickel and 0.3 lb. of molybdenum per gear. Heat treating time was decreased, material handling was simplified, and it is claimed that the change resulted in a tenfold increase without sacrificing quality. (J2g, T7a; ST)

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**The coding symbols refer to the ASM-SLA Metallurgical Literature Classification, International (Second) Edition, 1958*

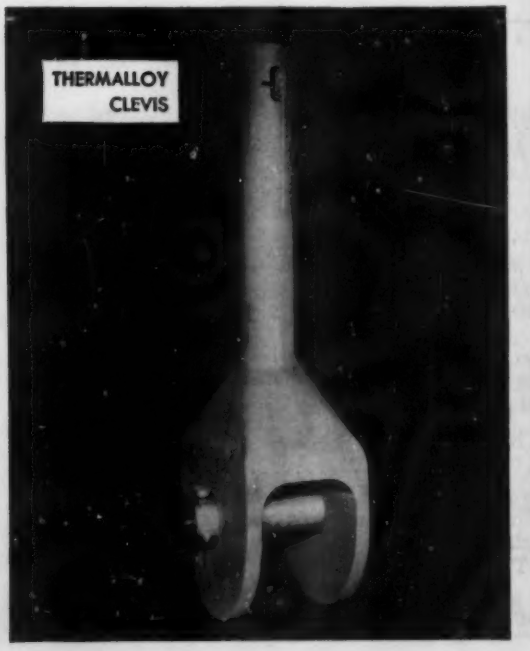
Thermalloy clevis design simplifies the heat treatment of large forgings

A manufacturer of large forgings uses the Thermalloy* clevis to heat-treat forgings weighing 30,000 to 74,000 pounds. The heat-treatment cycles range up to 300 hours with a maximum temperature of 1850°F.

Engineers from Electro-Alloys and the manufacturer working together developed the clevis for this heat-treating operation. The original lifting rig weighed four times as much as the Thermalloy clevis that replaces it. This reduces the total weight the crane must support in the furnace. The Thermalloy clevis simplifies lifting the forging by eliminating the wedging adjustment. Further, it eases the problem of positioning the forging in the furnace.

For advanced heat-resistant alloy-casting design service, contact your local Electro-Alloys representative or write: Electro-Alloys Division, American Brake Shoe Company, 9039 Taylor St., Elyria, Ohio.

*Reg. U. S. Pat. Off.



Brake Shoe

ELECTRO-ALLOYS DIVISION • Elyria, Ohio

Another Turbogenerator Failure, by R. James Landrum 91
Another failure in a turbogenerator, similar to the accidents in Toronto described in *Metal Progress* for July 1956, was due to the presence of fatigue cracks at ventilating holes. These acted as stress-raisers during temporary and minor overspeeding, inducing an almost instantaneous brittle failure which wrecked the machine—fortunately without human casualty. (Q26s, Q7, W11q, 17-51; AY)

Powder Metallurgy of Refractory Metals, by Alan Blainey 93
Hydrostatic compaction, extrusion of canned powders, and compression within deformable frames are interesting techniques utilized for cladding fuel elements with pure refractory metals and making special shapes for atomic power reactors. (H-general, T11g; Zr, Cb, V, Be, Mg)

Present and Future Uses of Titanium, by Paul M. Tyler 109
Titanium sheet and forgings now cost so much that uses are restricted; 90% of American production goes into jet engines for the Air Force. In a mature industry with integrated plants, costs would be cut to one fifth, thus opening large new markets in chemical equipment and wheeled vehicles. (A4s, 17-57; Ti)

Recent Statistics on Metallurgical Education, by W. O. Philbrook 113
Nearly 10% more degrees in metallurgy were granted in 1957 than in 1956. The number of B.S. degrees fell just short of 600, but was up 9.5% over the previous year. Masters', with 176 degrees, were up 8%. Doctors' totaled 83, up 9%. (A3g)

Producing for the Supersonic Age

Brazing Alloys for Guided Missiles, by A. T. Cape 99
Many types of brazing alloys are available and the selection of the right one for the job depends on such factors as kind of materials to be joined, service to which it will be subjected and methods of brazing which are to be used. (K8, T24c; SGA-f)

Welding the Refractory Metals, by L. F. Yntema 105
Tantalum, columbium, molybdenum and tungsten are used on many devices operating at high temperatures because of their high melting points and high-temperature strength. Because of their reactivity with air and their affinity to low-melting metals, they require careful control of welding variables. (K-general; EG-d, Ta, Cb, Mo, W)

Critical Points

Heat Treating Rocket Cases 65
Elaborate setup includes salt bath quench, water rinse and two tempering furnaces.

Data Sheet

Hardness Conversions, Knoop Versus Vickers, by Lloyd Emond 96B
Explanatory text and illustrations on p. 97.

Atomic Age

Euratom 98
Paraphrase of 24th Semi-Annual Report of the U.S. Atomic Energy Commission.

Metals Engineering Digest

New Titanium Alloys 134
Evaluation of properties, particularly of alloy B 120 VCA for air and spacecraft.

Chlorine Improves Aluminum Welds 145
Minute quantities are added to the arc area during inert-gas metal-arc welding.

Production of Fourdrinier Wire 154
Service requirements, production methods, metallurgical problems involved.

Stress-Raisers in Engineering Parts 158
Three categories of common stress-raisers which lead to fatigue failure.

Calcium Reduction of Zirconium 194
Novel method whose practical utilization will depend on the economics involved.

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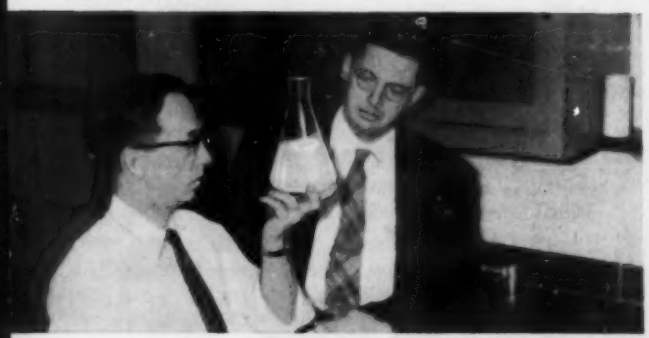
Metallurgical company—Called in to help settle a debate between plant engineers and safety department about where to put a large NH_3 tank, Herb Kerr's experience helped influence final decision. Later Kerr put in a 16-hour day helping to unload first tank car and get equipment running properly.

New manufacturer—Wanted to make household ammonia. Needed help to get started. Kerr conferred with Gar Ellis on laboratory test before suggesting equipment and recommending a supplier of an additive which was known to give the right degree of cloudiness.

Big chemical company—Problem: to recover NH_3 used as a solvent. Although customer preferred not to reveal full details of process, Kerr and George Cleek, Allied specialists, were able to devise for them an economical method for purification and recovery.



Chemical specialty company—Small, new at using NH_3. Bought some war surplus tanks, ran into problems, called Allied. "Zeke" Sziklas responded. Checked equipment they had, recommended additions, lined up contractor to install.

Paper mill—was considering ammonium bisulfite pulping. Allied worked out complete plans for NH_3 equipment required. Herb Kerr checked with "Westy" Westlake of engineering research before proceeding on trip to be on hand at startup—and for another three days—to make sure operations would continue smoothly.

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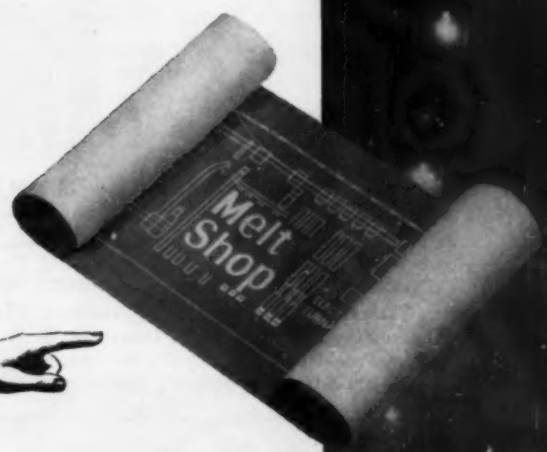

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This 32-page catalog will help you determine how Heroult Electric Furnaces can improve your operation and enable you to make better-quality steels; tells you when and where an electric furnace is logical; gives types, sizes, capacities and ratings. For your free copy, get in touch with any of the offices listed below or write direct to Pittsburgh.

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How steam treating affects ferrous and non-ferrous metals

Use of steam atmosphere is nothing new to industrial processing but the benefits to be realized from its application in the heat treating of metals have only begun to be explored in the past few years . . . and are currently attracting an increasing amount of attention.

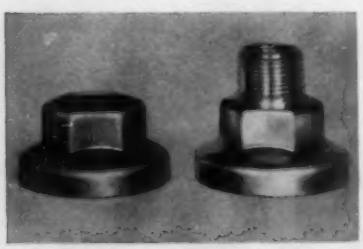
In scores of plants, working with both ferrous and non-ferrous metals, steam treating has proved an outstanding cost-cutter, according to F. L. Spangler, Application Engineer.

These trays of sewing machine parts are loaded for steam treating to give them a uniform, blue-black, wear-resistant finish. Since replacing the previously used bath method, steam treating has resulted in a 90% saving in direct labor and a reject problem has been eliminated.

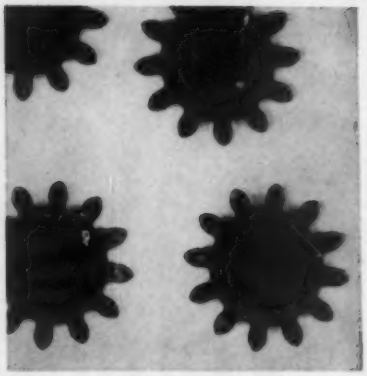
On high-speed steel cutting tools, for instance, it keeps tools sharp longer. Many drills, reamers, hobs, milling cutters, broaches, saws and similar tools hold their cutting edges 50 to 100% longer when steam treated after tempering and final grinding. This ratio goes up . . . often as high as 6 to 1 . . . when cutting such extra tough materials as alloyed structural steels.

On powdered iron parts, compressive strength and hardness increase appreciably. Tests of steam treated sintered compacts indicate that yield point under compression is twice that of a regular sintered compact.

To structural steel steam treating gives a uniform, corrosion-resistant, blue-black finish. When steam treating replaces chemical surface treatment, costs are usually 20 to 25%



These brass radiator steam-vent shells require nine draws and four anneals. Prior to use of a steam Homo furnace, a pickle was necessary after each anneal and a heavy pickle and buffing before final chrome plating. With steam treating the manufacturer has been able to eliminate all pickling . . . now uses only a bright dip and has substantially cut buffing time.



Powdered iron gears measuring 1¼" in diameter were tested for hardness on a standard Rockwell machine, before and after steam treatment. After steam treating, ten parts tested showed an average increase in hardness of 43% on the gear teeth . . . 112% on gear hubs . . . and a 26% increase in compressive breaking load.

less . . . where it is used for stress relieving or tempering prior to machining or grinding, a shot or sand blasting operation can be eliminated.

On gray iron castings steam seals microscopic porosity, improves resistance to wear and gives a high degree of corrosion resistance. Salt spray tests indicate that parts so treated stand up as well or better than cadmium plated ones.

Applied to non-ferrous metals . . . brasses, bronzes, beryllium copper, aluminum, etc. . . . it produces scale-free work ready for bright dip or use as-is. Within the past few years many manufacturers have substantially reduced and in some cases eliminated cleaning operations by stress-relieving, drawing, solution-treating or age-hardening in a steam atmosphere instead of air.

The equipment for this highly versatile heat treating method is safe and inexpensive...is ideal for installation directly in production lines.

A new 24 page catalog, *The Homo Method of Steam Atmosphere Heat Treating, gives details about application of the method to a variety of parts and materials. These specific instances may suggest ways in which this unique method can go to work for you to improve product quality . . . eliminate needless operations . . . reduce costs. Just write to Leeds and Northrup Company, 4927 Stenton Avenue, Philadelphia 44, Pennsylvania and ask for Catalog TD2-620(1).*

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Let's LAUGH a minute

Of course everyone knows that heat treating today has become one of the most serious technical and vital functions of the current metalworking activity. But a smile and laughter are still also important and the cartoons shown here are for that purpose.

We hope they make you grin and when it's heat treating services you require or skilled, technical advice about part design or heat treatability, check with

METAL TREATING INSTITUTE
271 NORTH AVENUE
NEW ROCHELLE, NEW YORK

or any member listed below.

Sound Familiar?
SMEAGACABE, THE PRODUCTION MAN, SCHEDULES A JOB THROUGH HIS PLANT WITH TIME TO WASTE!
LET'S SEE... PLENTY OF TIME FOR A GOOD JOB ON OPERATION 1 ... NUMBER 2 SHOULD BE ABLE TO CHUG ALONG ... NICELY ... ANPLE TIME FOR OPERATION NUMBER 3 ... THEN OUT IT GOES FOR HEAT TREATMENT
BUT... WHEN THE HEAT TREATING GETS IT ... IT'S IN AN AWFULLY GREAT HASTE!
SMEAGACABE! HOW'S THAT JOB COMING? TIME'S RUNNING OUT!
FINE, BOSS! I GOT IT TO THE HEAT TREATER 10 MINUTES AGO. I'M CHECKING WITH THEM NOW!
HELLO! ABC HEAT TREATING? WHAT'S HIT THROUGH WITH OUR JOB? DO YOU REALIZE WE HAVE A TIGHT SCHEDULE? TRYING TO MAKE ME LOOK BAD, HUH? ...BLAH, BLAH, BLAH ...

Sound Familiar?
CARELESS HELPER IS NOT PARTICULAR ABOUT THE PARTS HE SENDS IN FOR HEAT TREATING
BUT... TAKE A LOOK AT THIS CASTING!
... OFF SIZE, BY EXCEL CRACKED AND WHAT HAVE YOU. HOW DID IT EVER GET OUT OF THEIR PLANT ... OR DON'T THEY CARE?
Acme Heat Treating Co.
BUT... WHEN HE GETS THEM BACK ... WHAM! LOOK WHO GETS THE BLAME!!
CALL YOURSELVES METAL TREATERS? HAH! YOU SURE GIVE OUR CASTINGS THE 'TREATMENT'! - THEY GO OUT OF HERE 100% PERFECT, ... AND WHAT HAPPENS? DO YOU DROP 'EM OFF THE ROOF OR JUST RUN A TANK OVER THEM? IF YOU HAVE NO CONSIDERATION FOR A CUSTOMER'S PRODUCT I'LL JUST HAVE TO ...

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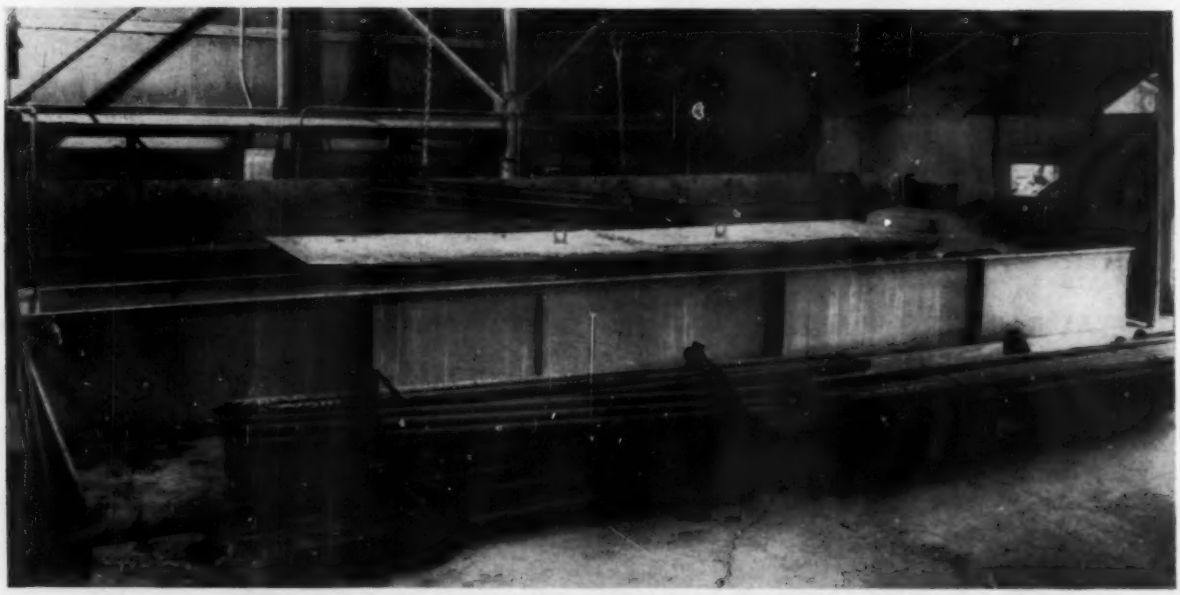

FROM 90 MINUTES TO 30 MINUTES

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It used to take as much as ninety minutes of straight acid pickling to descale these stainless steel tubes at the Gambrinus Works of The Timken Roller Bearing Company.

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The Virgo bath is safe and simple to operate, using normal precautions. Bath temperatures run from 800 to 1250°F.

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For more information on how Virgo Descaling Salt works, write for Bulletins 25 and 25-T (Titanium).

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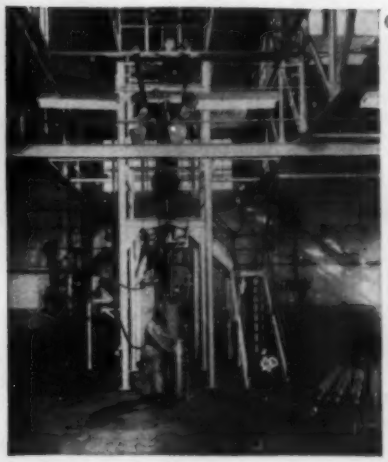
AIR ARC



CONSUMABLE ELECTRODE
(STERCON)

INDUCTION VACUUM
(STERVAC)

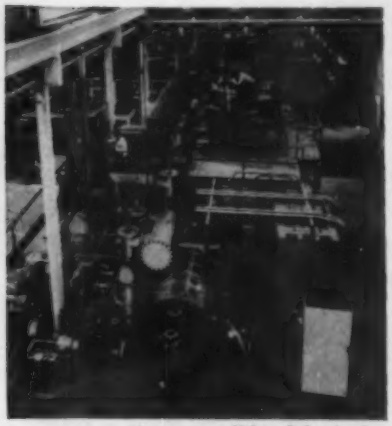


Photo courtesy Kolcott Industries, Inc.

Using Three Basic Melting Methods

to produce tougher high temperature alloys

Firth Sterling metallurgists have exceptional experience in *all three* basic melting methods—air arc, consumable electrode (STERCON) and induction vacuum (STERVAC)—used to produce high temperature alloys and super alloys to specification for the aircraft and missile industry. This unique combination of experience and facilities is available to you in developing high temperature materials with the purity, quality and mechanical properties essential to your applications.

For over 68 years, Firth Sterling has pioneered the development of tougher, more heat-resistant metals. The critical high temperature alloys produced for jet engine applications such as buckets, turbine wheels, shafts, compressor wheels, casings and blades, and structural rings and support members, are examples of Firth Sterling metallurgical achievements in meeting *today's* requirements. This valuable experience, capacity and technological "know how" are being applied to STERCON and STERVAC super alloys as well as basic metals such as Zirconium.

* *

For your high temperature alloy requirements involving quality and exceptional mechanical properties call on our practical metallurgical experience and modern melting facilities. Your Firth Sterling representative will give you complete information. Firth Sterling, Inc., Dept. 13-J, 3113 Forbes St., Pittsburgh 30, Pa.

"Your Future is Great in a Growing America"

PRODUCTS OF *Firth Sterling* METALLURGY

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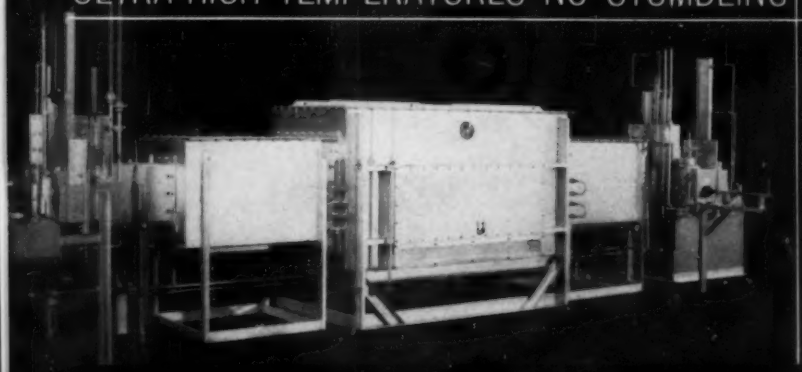
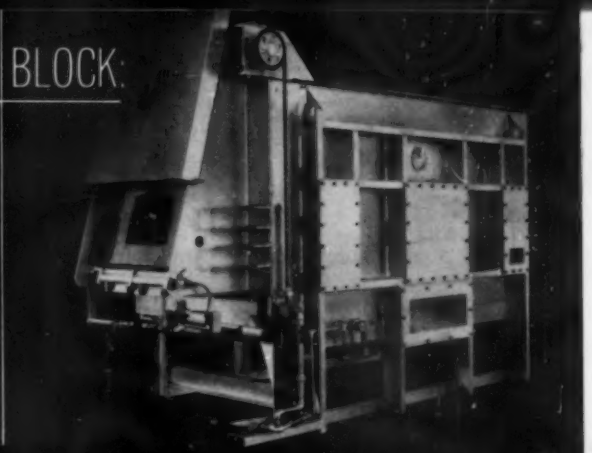
SINTERED TUNGSTEN CARBIDES • HEAVY METAL • CERMETS • CHROMIUM CARBIDES
ZIRCONIUM • TITANIUM • STERVAC & STERCON SUPER ALLOYS

FIRTH STERLING TRADE MARK

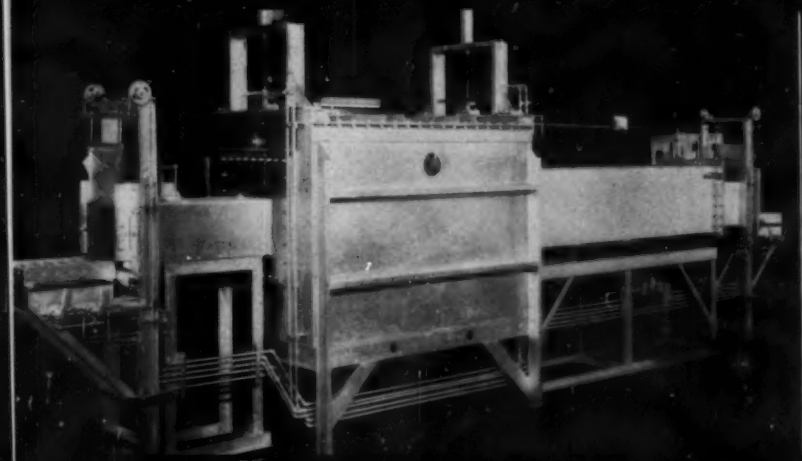
ULTRA-HIGH TEMPERATURES NO STUMBLING BLOCK:



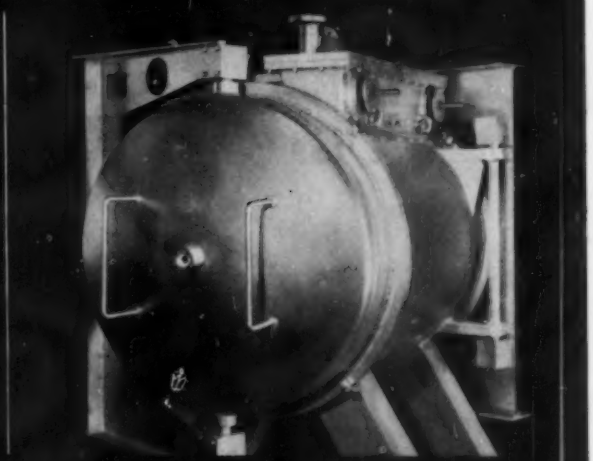
Sintering as many as 1250 UO_2 fuel pellets per hour in a hydrogen atmosphere, this Harper continuous pusher furnace is equipped for semi-automatic operation at temperatures up to 1750°C. Designed for gradual heating and cooling. Furnace has rugged moly heating elements, pressure relief vents, entrance and exit purge chambers.



Operating at temperatures as high as 1600°C, this single-ended batch furnace heats moly billets (up to 110 lbs./hr.) in a hydrogen atmosphere. Equipped with moly elements, it has two zones of heat control.



Sintering tungsten alloys (up to 75 lbs./hr.) in an atmosphere of dissociated ammonia, this moly furnace operates at temperatures as high as 1500°C. Designed for quick transfer from hot zone to cooling zone in atmosphere, it is equipped with pneumatically lifted refractory baffle doors for temperature uniformity.



Sintering stainless steel and tungsten powder parts at temperatures up to 2000°C, this Harper moly box furnace operates with mixtures of inert and reducing atmosphere gases.

MOLY FURNACES SUCCESSFUL UP TO 2000°C

As furnace operating temperatures rise above 1300°C (2350°F approx.), problems multiply. For example:

- What is the best combination of atmosphere and heating elements to obtain results desired?
- What refractories will prove most practicable from the standpoint of process, economy and service?
- Are purge chambers desirable or necessary?
- How should purge chamber doors be built to insure atmosphere-tight operation?
- When should automatic gas purging and automatic door sequence control be provided for quality, safety and economy?
- How should refractory baffle doors, roofs and hearths be constructed?

It takes experience to come up with the most profitable answers to questions like these in any given situation . . . *and Harper has experience to spare.* The four molybdenum heated units pictured above are but a few of many furnaces that have been built by Harper for high temperature applications. Among others are graphite tube models which perform with creditable success at 2750°C (5000°F approx.).

No matter what type of furnace you have in mind — box, pusher, mesh belt, roller hearth, bell, elevator or pit — Harper can supply it to operate most advantageously both temperature-wise and dollar-wise.

For more information, talk to your Harper representative or write: Harper Electric Furnace Corporation, 40 River Street, Buffalo 2, N. Y.

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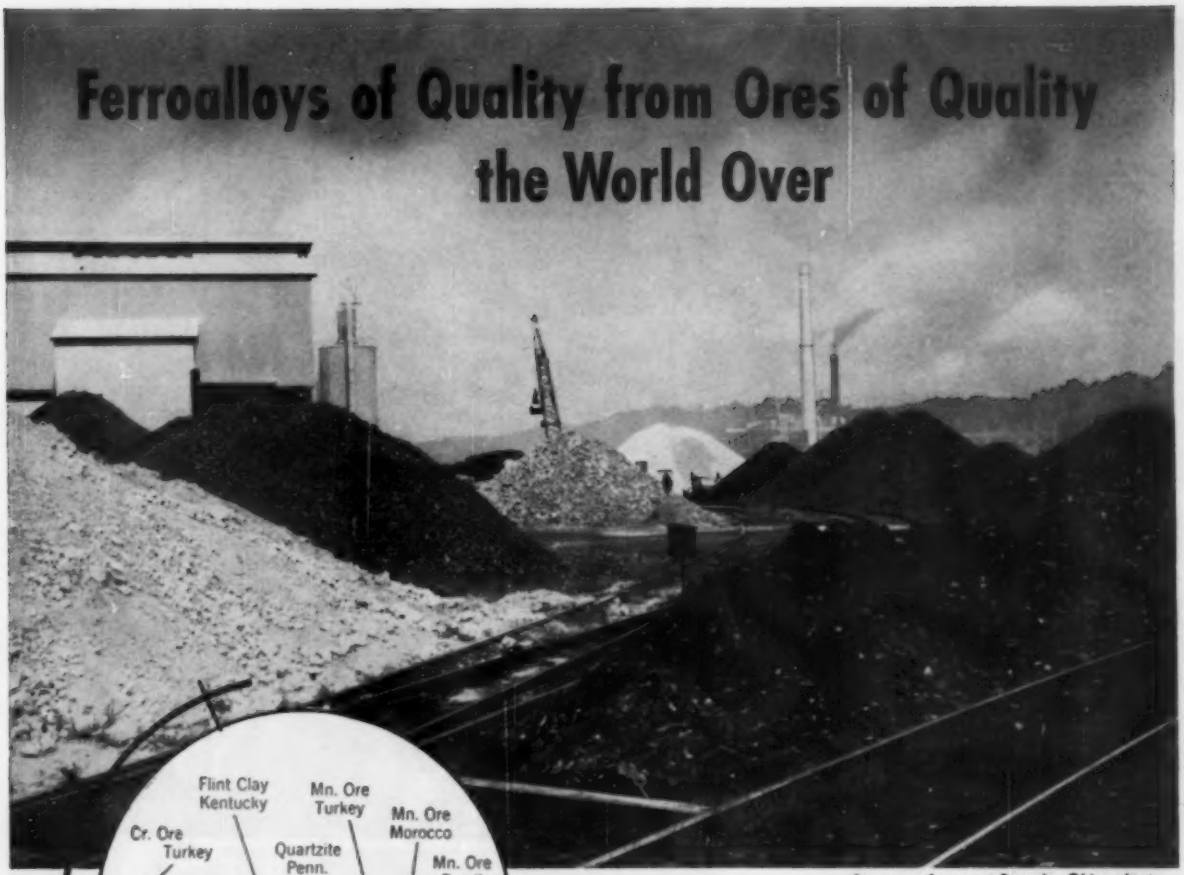

Storage of ores at Beverly, Ohio, plant.

From the finest deposits throughout the world come ores—after painstaking sampling and testing at mines and docks—for Globe Ferroalloys.

Thus . . . quality starts at the source, and *quality control* is strictly maintained throughout the production of Globe Ferroalloys. The result—dense, clean ferroalloys of maximum physical and chemical consistency with a minimum of residual elements.

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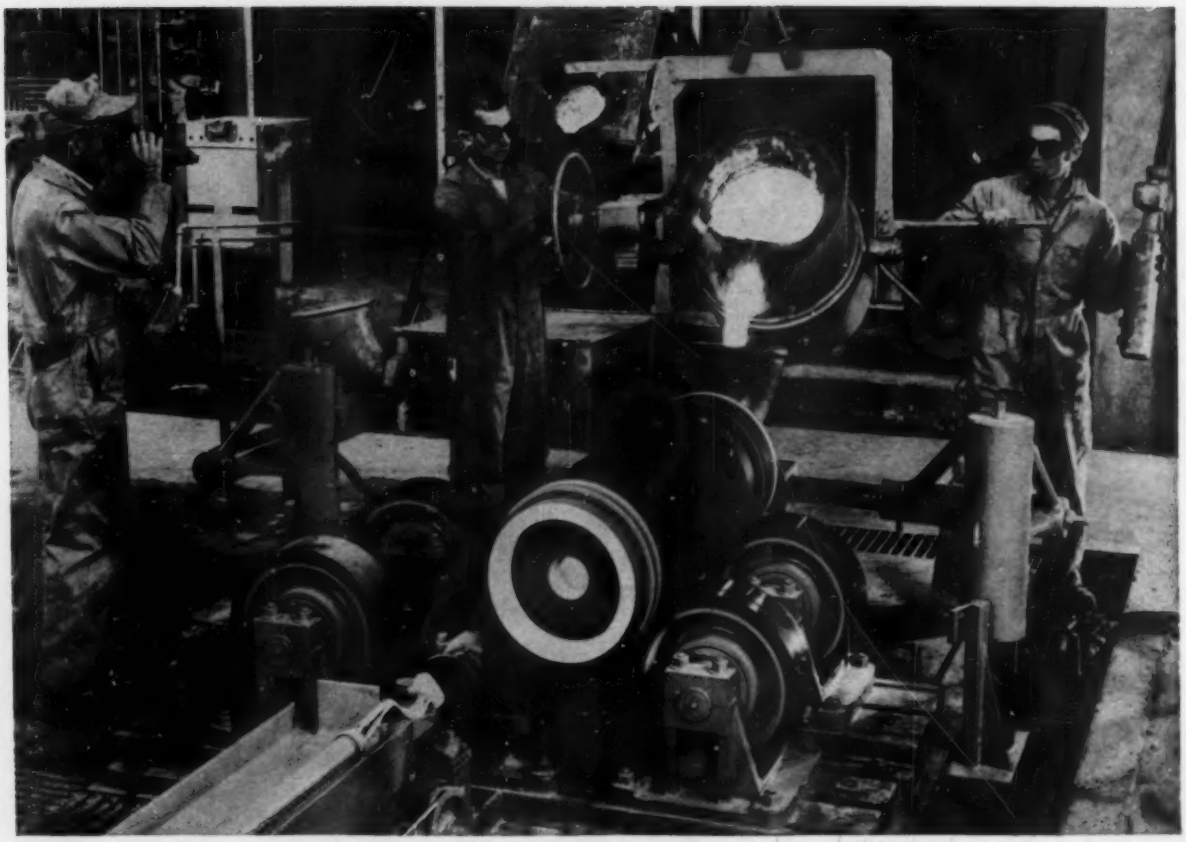


WHY GOOD CENTRIFUGAL CASTING DEMANDS INDUCTION MELTING

Though centrifugal casting has values apart from any melting furnace used, it achieves its ultimate performance only with induction melted metals. You may have wondered yourself why the vast majority of critical centrifugal castings are poured from Ajax-Northrup induction furnaces. The reasons are many—

Take purity for example. One major advantage of centrifugal casting is that the spinning concentrates impurities such as dirt, slag particles, even gas, at the internal skin, where they can be machined away easily. Obviously, the purer the melt, the thinner the skin to be machined. And Ajax-Northrup induction melting has proved itself many times over to be the purest melting method known!

Or take uniformity. The electromagnetic stirring action inherent in the Ajax-Northrup induction furnace assures absolute uniformity of chemical composition and temperature throughout the melt, resulting in consistently homogeneous castings, even with alloys containing metals of widely varying densities such as Al, Ni, and Mo. In fact, users have been able to eliminate uniformity tests on Ajax melted centrifugal castings entirely.

The precise metal temperature control available with Ajax-Northrup induction equipment is another important consideration in the production of consistently uniform castings. Hot and cold pours are eliminated. And this combination of ideal temperature control and perfect mixing adds up to good, reproducible results.

Ajax-Northrup induction melting equipment, with its unique control system offers you maximum melting efficiency with resulting lower melting costs. The new compact designs incorporate many features which minimize floor space requirements, drastically reduce installation costs, minimize maintenance, and provide simple, more efficient operation.

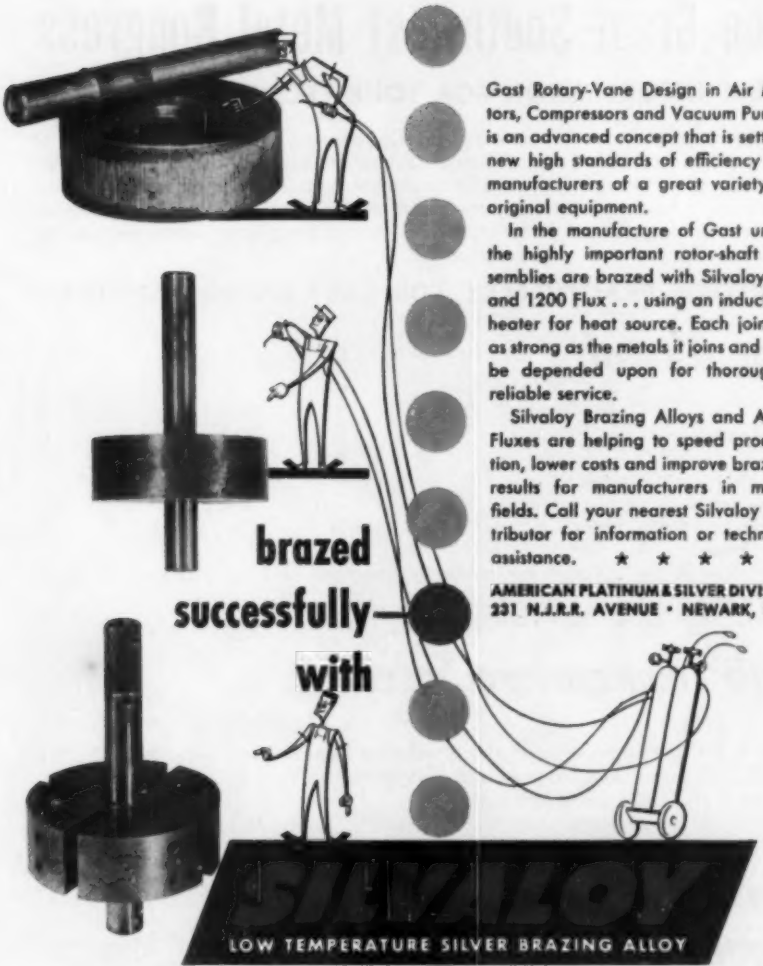
Induction heating & melting

AJAX

NORTHRUP

Whether you're centrifugal casting tiny investment castings, massive rolls, or critical jet engine tail sections, you're sure to find an Ajax furnace that satisfies your needs perfectly. We'll gladly send you further information, or, if you wish, arrange a meeting with qualified furnace engineers to discuss your special requirements. Ajax Electrothermic Corporation, Ajax Park, Trenton 5, New Jersey.

ASSOCIATED COMPANIES: AJAX ELECTRIC COMPANY-AJAX ENGINEERING CORPORATION



Gast Rotary-Vane Design in Air Motors, Compressors and Vacuum Pumps is an advanced concept that is setting new high standards of efficiency for manufacturers of a great variety of original equipment.

In the manufacture of Gast units, the highly important rotor-shaft assemblies are brazed with Silvaloy 45 and 1200 Flux . . . using an induction heater for heat source. Each joint is as strong as the metals it joins and can be depended upon for thoroughly reliable service.

Silvaloy Brazing Alloys and APW Fluxes are helping to speed production, lower costs and improve brazing results for manufacturers in many fields. Call your nearest Silvaloy Distributor for information or technical assistance. ★ ★ ★ ★ ★

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GAST MANUFACTURING CORP. is one of the country's most creative manufacturers of rotary air motors, compressors and vacuum pumps for original equipment markets. The large plant is located at Benton Harbor, Michigan.

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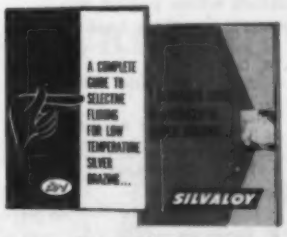

Two complete reference manuals for low-temperature silver brazing and fluxing are available upon request. Send for either one or both. ★ ★ ★ ★ ★ ★ ★

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This shell for a Dyna-Empire, Inc. hearing aid button speaks loud and clear to *everybody* concerned with precision in screw machine parts. No larger than a penny, with walls only .006" thick, machined to within .001" tolerances, it proves just how precisely we put the metal where you want it.

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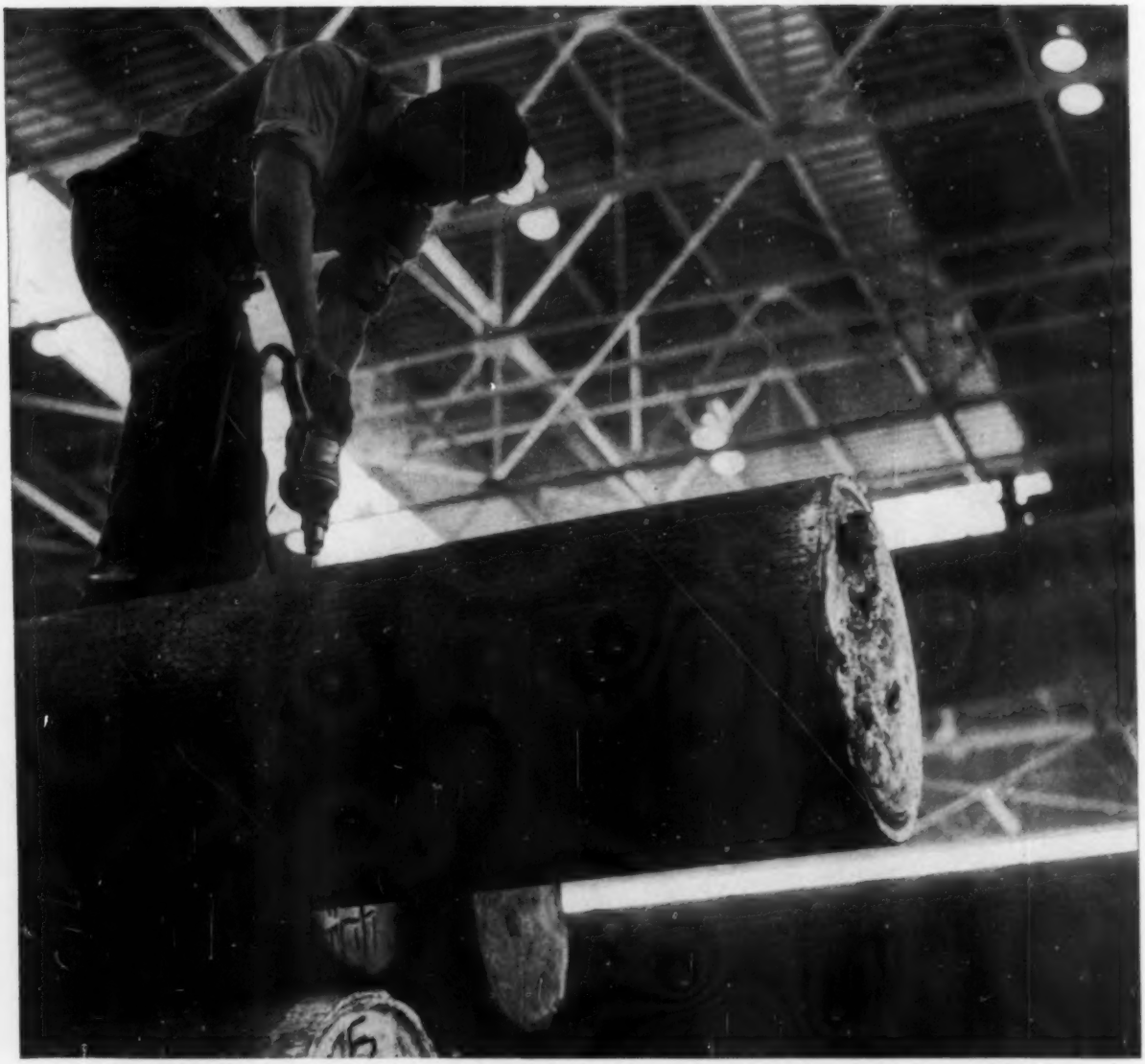

Kaiser Aluminum ingots being prepared for "homogenizing" in Gas-fired furnaces prior to extrusion into aircraft parts

GAS assures precision alloy extrusions at Kaiser Aluminum

Gas plays a major role in the development of precision quality alloy extrusions for aircraft at the U. S. Air Force Heavy Press Plant operated by Kaiser Aluminum at Halethorpe, Maryland.

With Gas, uniform temperature and controlled atmosphere keep molten aluminum flowing smoothly into casting equipment. The metal is cast into logs about 12 to 26 inches thick and 25 feet long. Gas-fired furnaces heat the logs to 1000° F and hold this temperature about 24 hours to homogenize the metal prior to extrusion. The long logs are cut into 58 inch billets, placed on the press and extruded into various shapes.

Again, Gas is used to heat the extruded shapes in a controlled atmosphere to impart the desired physical qualities in the alloys used. As in the melting process, Gas provides precise temperature control and close control of atmosphere within the furnace.

For information on how Gas can help you in your production operations, call your Gas Company's industrial specialist. He'll be glad to discuss the economies and outstanding results Gas and modern Gas equipment provide. *American Gas Association.*

The Legendary Firebird, the Phoenix, rose young and strong again and again from flames . . . This is the new Norton Firebird—symbol for the exciting new fused materials made in Norton's electric furnaces.

ZIRCONIUM: gift of the Firebird

Like the legendary Phoenix, Norton electrochemicals are born in raging flames — armed with power to perform new wonders. Among these modern materials are zirconium compounds formed at terrific heat in Norton electric furnaces.

Today, zirconium compounds are among the most interesting developments of modern electrochemistry. Norton now supplies these to industry as oxides, carbides, borides and nitrides, as well as calcium zirconate.

While the complete extent of zirconium's usefulness has not yet been fully explored, the Norton compounds of this element offer many new applicational possibilities — as source materials, metallurgical additives, cermet components, electrical conductors and refractories.

So do many other products of Norton electrochemical engineering, one or more of which may be vital aids to your own processing.

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Gifts of the Firebird: compounds of silicon • zirconium • boron • aluminum • magnesium • titanium • chromium . . . including many borides • carbides • nitrides • oxides

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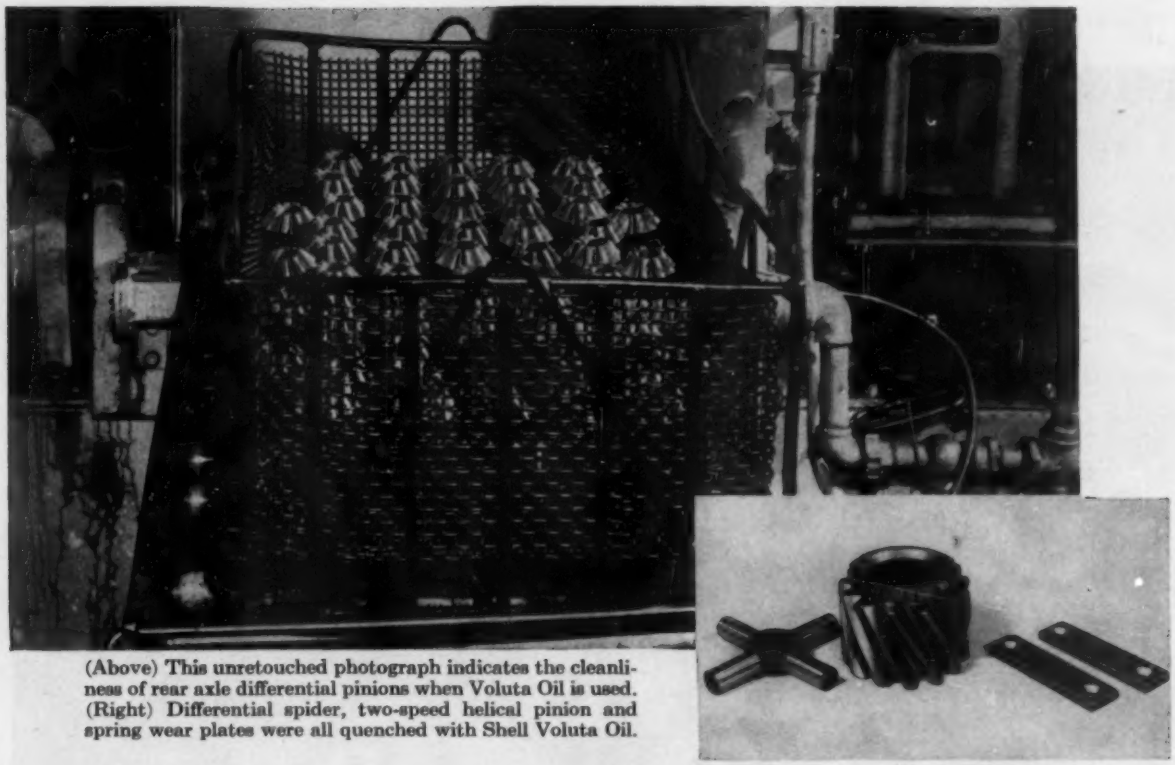


(Above) This unretouched photograph indicates the cleanliness of rear axle differential pinions when Voluta Oil is used. (Right) Differential spider, two-speed helical pinion and spring wear plates were all quenched with Shell Voluta Oil.

Here's a stable, high-speed quenching oil that minimizes work distortion

There has long been an urgent need for a uniformly stable quenching oil that would perform satisfactorily with minimum distortion of the workpiece. During the quenching operation, fluid deterioration can occur, causing sludge and acid formations which in turn result in non-uniform physical characteristics of quenched parts.

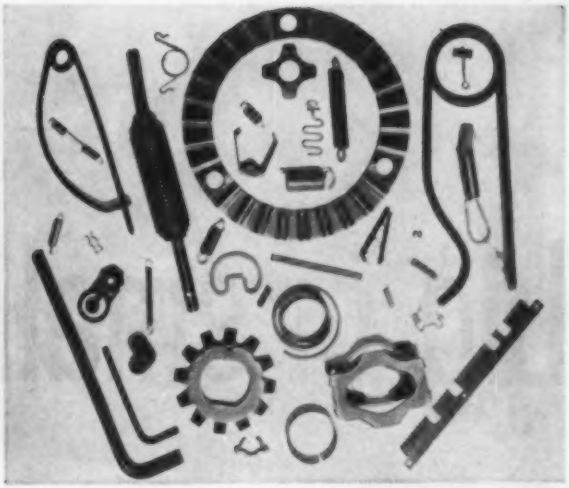
An efficient and timely answer to this industry problem is found in Shell Voluta Oils. They satisfy the two basic requirements of a high-quality quenching oil: 1) They remain stable at temperatures much higher than heretofore allowable, with no appreciable sludge formation. 2) They permit safe, rapid quenching of parts which have a tendency to distort. This is in part due to the higher permissible fluid temperatures, and also to the greatly enhanced wetting qualities of Voluta* Oils.

There are many applications that clearly demonstrate the efficiency and versatility of Voluta Oils.

One example relates to a leading producer of several thousand varieties of axle parts. With conventional quench oils, rejects were high due to unfavorable stress concentration and subsequent cracking. After changing to Voluta Oil, maximum uniformity was achieved because of Voluta's superior wetting-out properties and stable cooling rate. For heat-treating purposes, Voluta Oils proved stable at temperatures from 130° to 200° F. They also provided greater surface hardness, depth of hardness and uniformity.

A well-known manufacturer of automotive steering units was faced with a similar situation. Here the problem involved heat-treating low-carbon-steel parts as well as grey-iron castings. Although they were of widely varying materials, shapes and sizes, this company found that

Shaker hearth furnace automatically dumps parts into Shell Voluta Oil, then removes and drains them.



Over 35,000 prints of production items like these (quenched in Voluta Oil) are kept on file by one leading steel spring manufacturer.

Voluta Oil was far superior in all these ways: 1) longer life; 2) clean, scale-free parts; 3) wider range of quench temperatures; 4) no rejects due to distortion; 5) no sludge formation.

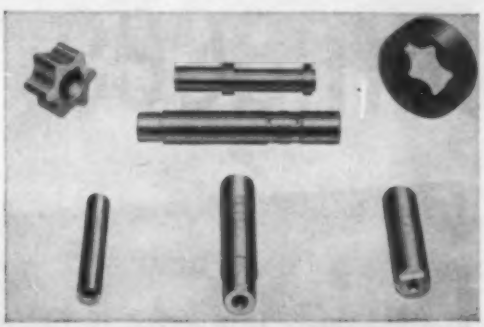
Still another case occurred during the manufacture of many thousands of different shaped springs. This company wanted to insure maximum elasticity of their springs, and to achieve this a 100 per cent martensitic structure had to be maintained. Tested in competition with several other quench oils, Shell Voluta Oil again proved superior because it resulted in the production of distortion-free springs, and allowed quicker drainage and minimum dragout loss.

Another feature: Voluta affords substantial savings on a yearly basis . . . and it further proves its economy in reduction of rejected parts.

Perhaps you have a similar quench problem . . . or any quench problem, for that matter. It would be to your advantage to call or write your nearest Shell Oil office. We'd be glad to have our representative discuss your particular quench problem and methods to help overcome it.

*Registered Trademark

Parts are heat-treated and quenched in two-zone hardening furnace while Voluta Oil's temperature is closely controlled.



Castings and low-carbon-steel parts for hydraulic steering units are all processed through the same heat-treating furnaces and quench tanks.

SHELL OIL COMPANY

50 WEST 50TH STREET, NEW YORK 20, NEW YORK
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SHELL

big or small, Surface mechanized furnaces pay off

Whether your volume is modest or vast—with short runs or long—there are many ways to profit from Surface experience in mechanizing heat treat equipment for ferrous and nonferrous metals. All of them give you uniform duplication of results; upgraded labor; reduced unit costs; expanded capacity; and strengthened competitive position

You may require a single batch type furnace, (right above) in which work is handled automatically from charge to discharge. For expanded facilities, a battery of such furnaces can be handled by one operator. Standard furnaces can also be linked in sequence to form an automatic heat treat line.

You might want your furnaces integrated directly with machines at separate points in your production line, (right center). This line processes bearing races from raw stock through a sequence of manufacturing operations—machining, heat treating, and finishing.

Your methods may call for a self-contained automatic heat treat line within your production line, (right below). Hoppers convert variable production from machining operations to the steady rate best for efficient heat treating. All operations are interlocked and continuous.

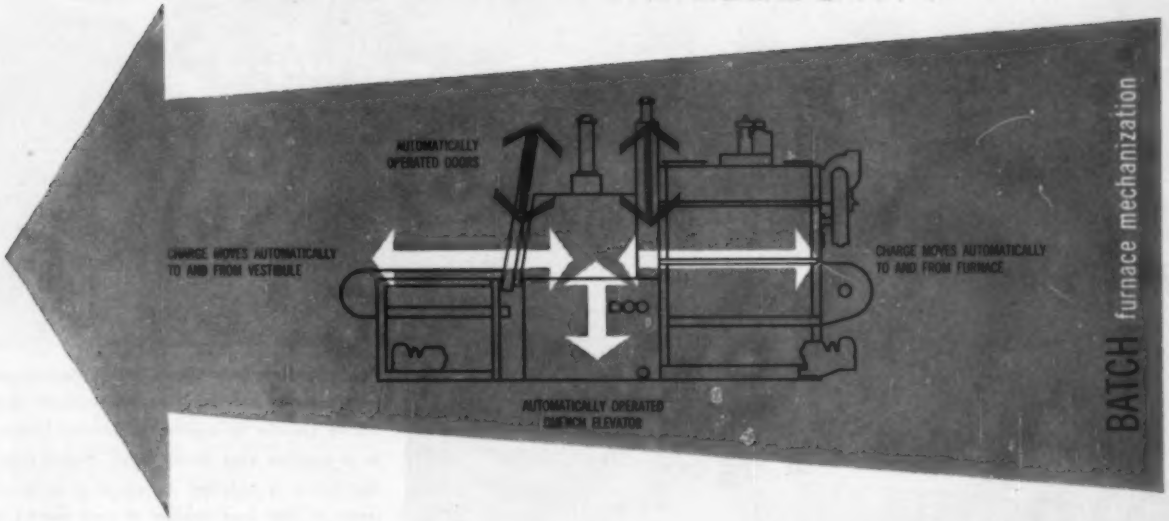
These are merely samples of the range and depth of mechanization know-how which Surface has accumulated since as far back as 1929. That was the date of installation of a completely automatic line for normalizing, hardening, and tempering transmission parts. Still operating, that line has paid for itself many times over.

Explore these advantages for your own operation; write for Bulletin SC-176.

Surface Combustion Corporation, 2377 Dorr St., Toledo 1, Ohio. In Canada: Surface Industrial Furnaces, Ltd., Toronto, Ontario.

Surface

wherever heat is used in industry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AUTOMATICALLY OPERATED QUENCH ELEVATOR
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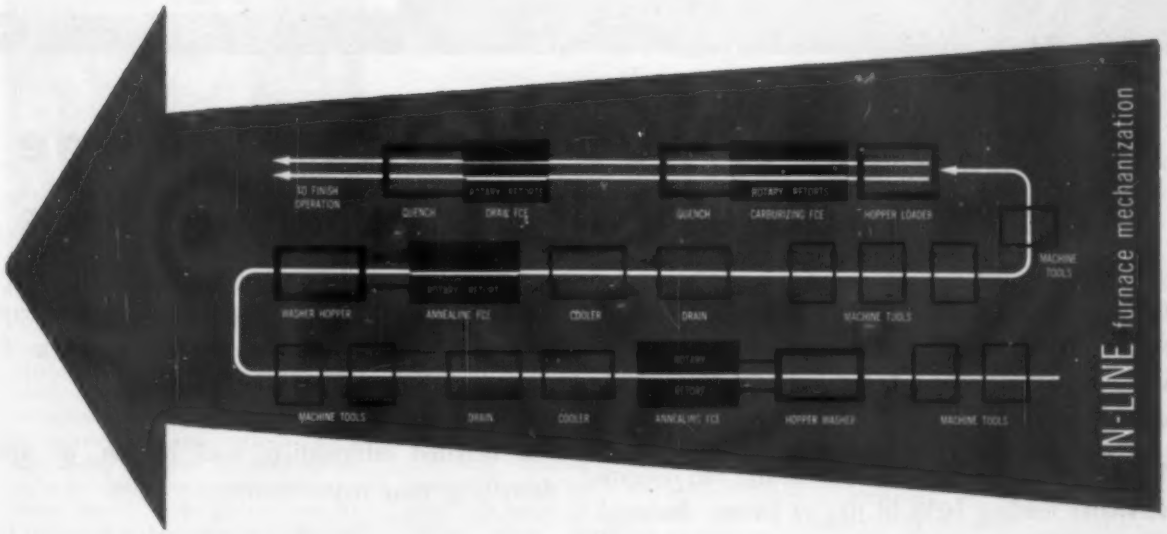
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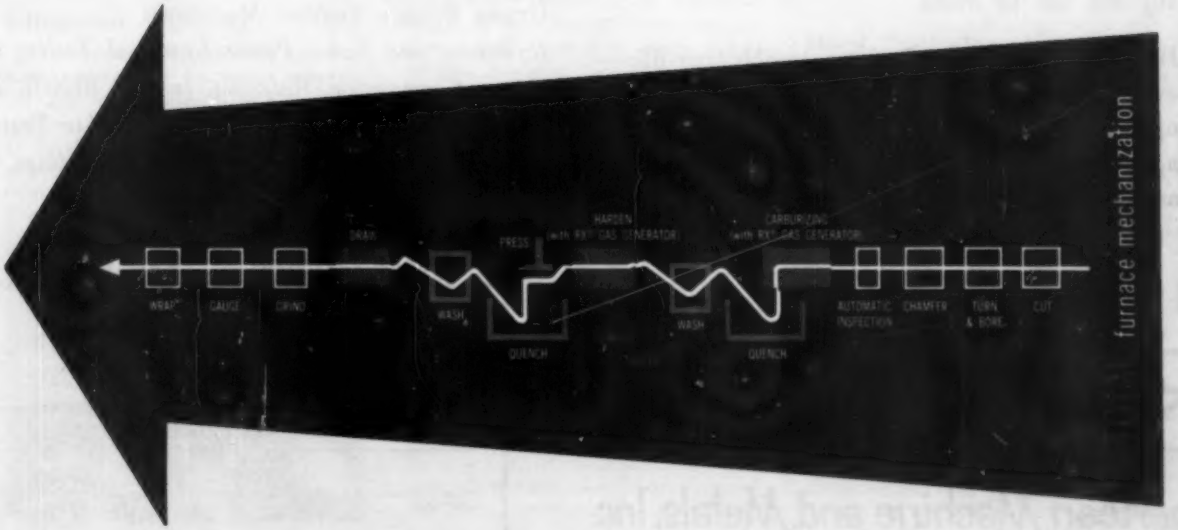
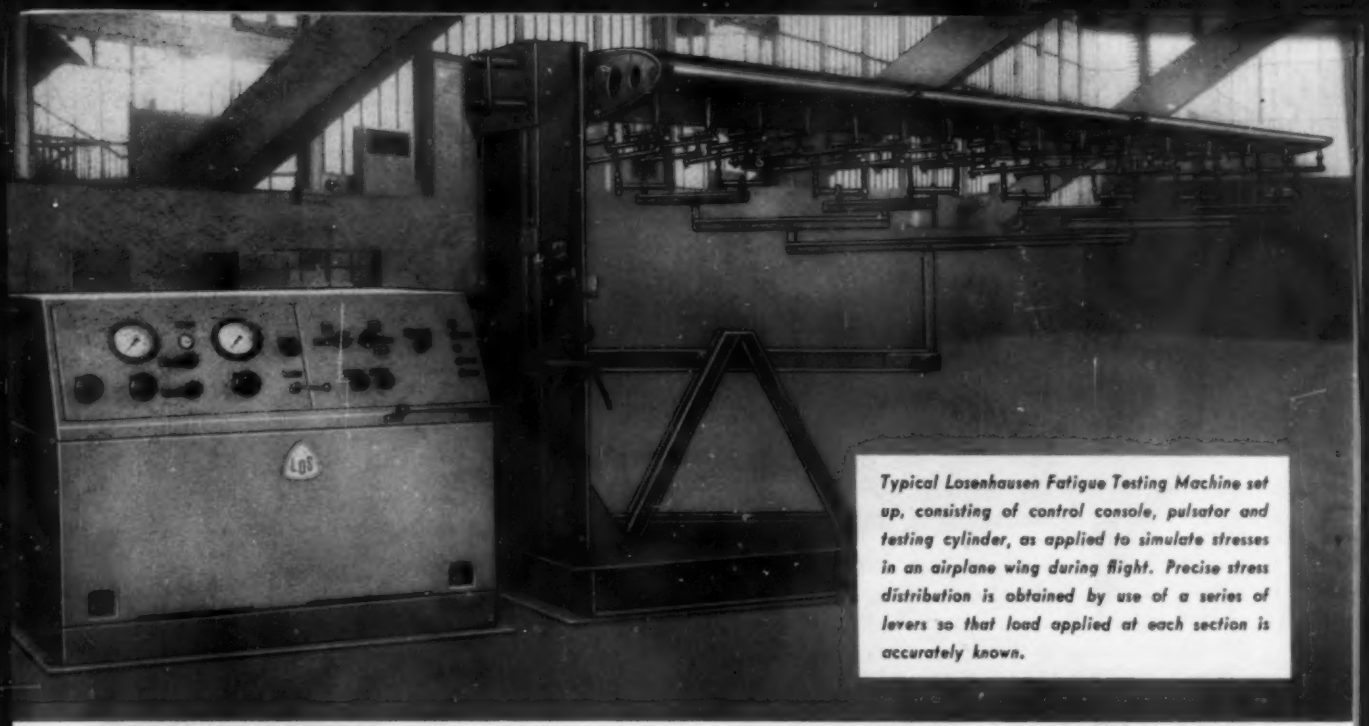
MACHINE TOOLS
WASHER HOPPER
ANNEALING FCE
COOLER
DRAIN
MACHINE TOOLS
MACHINE TOOLS
DRAIN
COOLER
ANNEALING FCE
HOPPER WASHER
MACHINE TOOLS
IN-LINE furnace mechanization


DRAIN
PRESS
HARDEN
CARBURIZING
WASH
GAUGE
GRIND
WASH
QUENCH
QUENCH
AUTOMATIC INSPECTION
CHAMFER
TURN & BORE
CUT
furnace mechanization



Typical Losenhausen Fatigue Testing Machine set up, consisting of control console, pulsator and testing cylinder, as applied to simulate stresses in an airplane wing during flight. Precise stress distribution is obtained by use of a series of levers so that load applied at each section is accurately known.

Versatile Fatigue Testing Machine Accommodates Full-Scale Assemblies

NEWLY AVAILABLE FROM RIEHLE, the Losenhausen fatigue testing machine makes possible testing of large components over a broad range of frequencies and applied loads.

The machine is hydraulic actuated, and can operate individual loading jacks in jigs or frames designed and constructed by the user, so components of almost any size can be tested.

Hydraulic design assures long, trouble-free life — even at high loadings. Machine is non-resonant and operates on load control principles. Both static load applications and dynamic loadings can be employed, and all testing can be fully programmed.

Strokes up to 10″ can be generated at low frequency, and modest strokes can be accommodated at frequencies approaching 3,000 cpm.

For detailed information, mail coupon, or write, describing your requirements.

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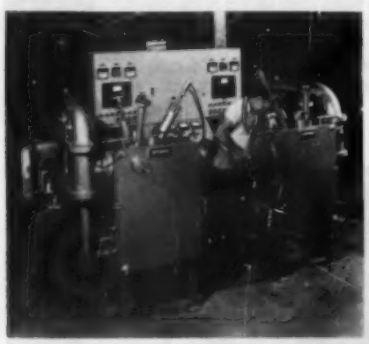
APPLICATION and EQUIPMENT new products

Vacuum Melting

A new series of vacuum induction melting furnaces, with capacities from 17 to 50 lb. has been announced by the Vacuum Equipment Div. of F. J. Stokes Corp. The new furnaces are delivered as complete packages. They are capable of handling molds



up to 27 in. high and 16 in. in diameter, and of pouring under 1 to 5 microns vacuum. They can be supplied as single units, complete with induction heating equipment and all instrumentation and controls; or as dual units, with two furnaces operating in tandem from a single induction power source (see picture above).
For further information circle No. 425 on literature request card, page 48-B.

Ultrasonic Cleaning

The General Ultrasonics Co. has announced a new ultrasonic processing tank with a capacity of 5 gal. The stainless steel treatment chamber is 14 by 9 by 10 in. It is powered by a generator with an output of 400 watts continuous at 20 kc. per sec. Ultrasonic energy is generated by

patented transducer elements, which are constructed mainly of solid steel sections. These are joined to the stainless steel treatment chamber by welded studs.
For further information circle No. 426 on literature request card, page 48-B.

Ferromanganese

A new alloy, ferromanganese-silicon, for the production of high-manganese stainless steels, has been announced by Electro Metallurgical Co. Ferromanganese-silicon is used both as a slag reducing agent and a source of low-carbon manganese. The analysis of ferromanganese-silicon is 63 to 66% manganese, 28 to 32% silicon, 0.10% max. carbon, 0.05% max. phosphorus, 0.03% max. sulphur.
For further information circle No. 427 on literature request card, page 48-B.

Thermocouple

Leeds and Northrup Co. has announced a new expendable immersion thermocouple for molten steel temperatures. It is said to be comparable in cost with present methods. The new equipment consists of a length of standard 1-in. black iron pipe with a handle on one end and a fitting on the other to hold the cartridge. The cartridge and a 4-ft. paper sleeve protecting the immersed length of pipe are the only expendable items. Both are easily pulled off and replaced for each reading. The cartridge itself is a refractory cylinder with contacts at the receptacle end and a platinum platinum-10% rhodium thermocouple enclosed in a U-shaped sheath extending from the immersion end. The couple's entire immersion end is enclosed by a hemispherical sheet steel cap, which melts away to expose the couple.
For further information circle No. 428 on literature request card, page 48-B.

Induction Melting

A new type of frequency converter, the Multiductor, has been announced by Ajax Electrothermic Corp. Essentially a static frequency converter, the Multiductor contains no rotating parts. A typical use of the Multiductor takes three-phase power at 60 cycles directly from regular or primary sources and converts it to single-phase power carried from converter to furnace by conventional wiring.

The three-phase load is inherently balanced at the Multiductor input connections. Output can be varied continuously and under load from zero to maximum and nothing can be damaged by overloads.
For further information circle No. 429 on literature request card, page 48-B.

Hard Surfacing

A new composite-coated hard surfacing electrode has been announced by Wall Colmonoy Corp. The new nickel-manganese alloy is a work hardening material that provides toughness at low temperatures. The new material deposits at approximately 229 Bhn.; it work hardens in service to as high as 555 Bhn. Walmag No. 3 conforms to AWS-ASTM Classification EFeMn-A covered.
For further information circle No. 430 on literature request card, page 48-B.

Processing Compound

Swift & Co. have announced a series of metal processing and anti-friction compounds which can be furnished for wet or dry processing

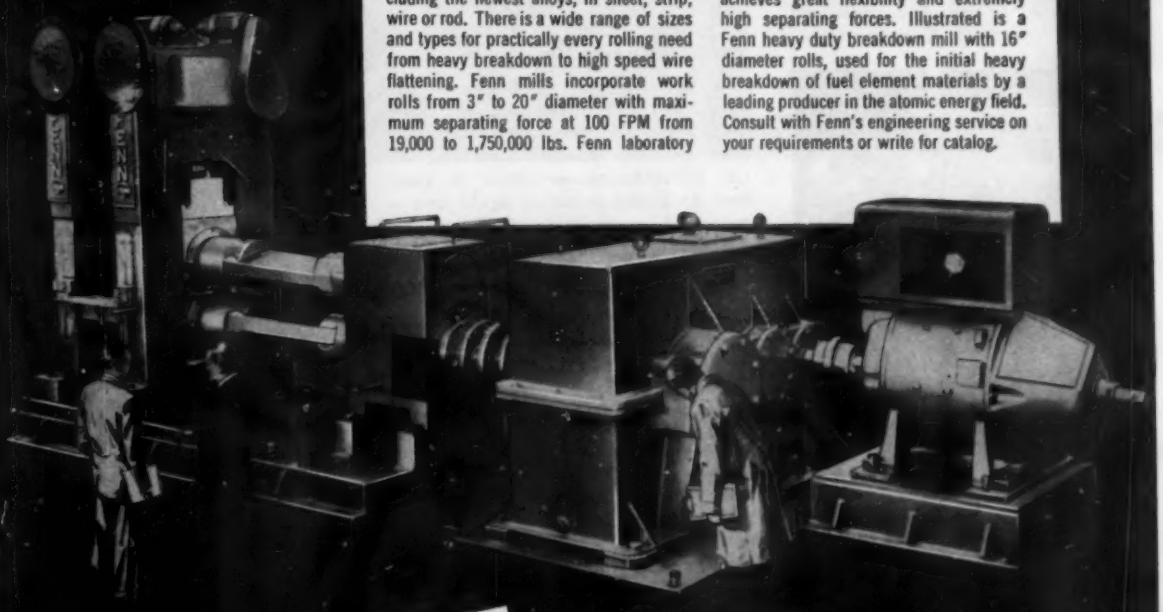
FENN *Sets the Pace*

in precision engineered

METAL FORMING EQUIPMENT

PRECISION ROLLING MILLS

Fenn manufactures a complete line of precision engineered Rolling Mills for rolling ferrous and nonferrous metal, including the newest alloys, in sheet, strip, wire or rod. There is a wide range of sizes and types for practically every rolling need from heavy breakdown to high speed wire flattening. Fenn mills incorporate work rolls from 3" to 20" diameter with maximum separating force at 100 FPM from 19,000 to 1,750,000 lbs. Fenn laboratory models are widely used in metallurgy, atomic research, and pilot run development. The inherent design of Fenn mills achieves great flexibility and extremely high separating forces. Illustrated is a Fenn heavy duty breakdown mill with 16" diameter rolls, used for the initial heavy breakdown of fuel element materials by a leading producer in the atomic energy field. Consult with Fenn's engineering service on your requirements or write for catalog.

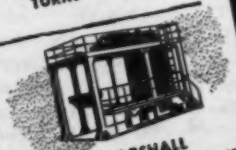


WIRE AND TUBE FORMING EQUIPMENT

WIRE SHAPING MILLS

TURKS HEADS

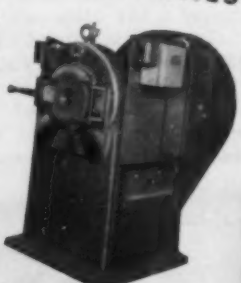
DRAW BENCHES



FAMOUS MARSHALL RICHARDS WIRE AND TUBE DRAWING MACHINES

ROTARY SWAGING MACHINES

Are you aware of the new techniques and equipment that are making rotary swaging increasingly important as a basic precision production process? Today, Fenn Swaging Machines perform an almost limitless variety of pointing, tapering, reducing, sizing and assembly operations. Fenn offers a most complete line to handle solid bar stock from 1/32" to 3 1/8", and tubing to 6". Fenn also manufactures hydroformers, swaging feeds, and swaging dies. Write for catalog.



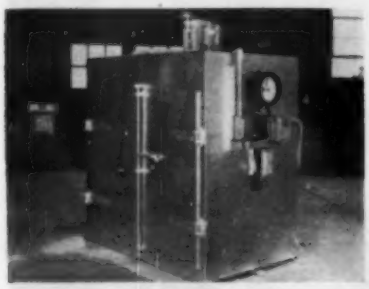
Whatever your metal forming requirements, it will pay you to consult with Fenn's direct factory sales engineer.

and in a water soluble or insoluble, solvent soluble or insoluble form. Included in the Flexal family are calcium stearate base lubricants, pure calcium stearates in a variety of forms, pure sodium stearates and specialty formulations of either the calcium or sodium-base product.

For further information circle No. 431 on literature request card, page 48-B.

Drying Oven

A new electric recirculating drying oven has been announced by the Pereny Equipment Co. This new unit is designed to operate at temperatures up to 300° F. and is heated by heating elements of the fin-strip type. A 1500 cfm. circulating fan is operated by a 1 hp., three-phase motor. Chamber size is 38 by 36 by 48 in. The oven is equipped with a seven-day timer and circular chart recorder-type controller. Connected load is 9 kw.



For further information circle No. 432 on literature request card, page 48-B.

Blast Furnace Plugging

Salem-Brosius has announced a new clay gun for stopping tap holes of blast furnaces, especially those of large capacity and high top pressure. All motions of the new clay gun are hydraulically actuated and electrically controlled through solenoids operating the hydraulic control valves. The standard gun delivers clay at pressures up to 800 psi. at the nozzle. The option of 12 or 15-cu.ft. clay barrels guarantees ample clay without refilling the barrel during plugging. By a mechanical wedge design, the nozzle of the gun is locked into the tap hole without mechanisms or latches mounted on the furnace or furnace columns.

For further information circle No. 433 on literature request card, page 48-B.

Barrel Finishing

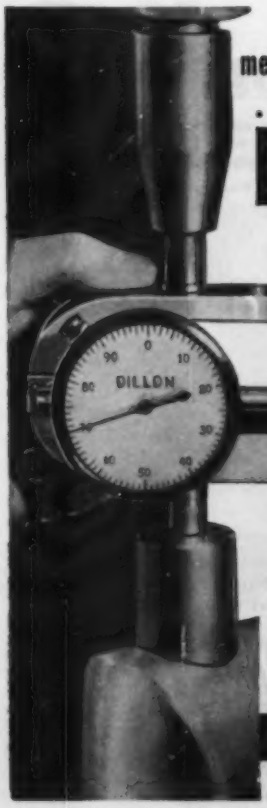
A new model of barrel finishing machines with a 30-in. diameter by 32 in. long barrel for high-volume finishing of small parts as well as large castings and forgings has been announced by Almco, Queen Products, Inc. Total barrel capacity of

13.8 cu.ft. or 1000 lb. can be divided into two compartments if desired. The barrel is driven by a 1½ hp. motor through a helical gear speed reducer. A variable speed control allows adjustment of barrel rotation speed from 10 to 30 rpm. Barrels are available with either Neoprene lining or unlined.

For further information circle No. 434 on literature request card, page 48-B.

Gas Generator

A packaged hydrogen gas generator for small and medium production has been announced by Gas Atmos-



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Checking the force exerted by electrodes of a spot welder is just one of many applications of a DILLON Pressure Gauge. It's a compact instrument that accurately measures compressive loads in *very small spaces* . . . flexes millions of cycles without loss of resiliency . . . sustains 25% accidental overload . . . incorporates jeweled dial indicator for extreme accuracy. Capacities from as low as 0-10 lbs. up to as high as 0-50,000 lbs. Low cost . . . immediate delivery!

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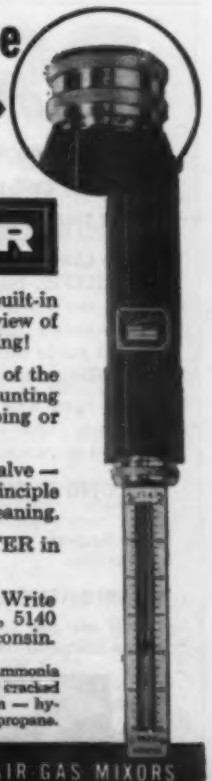

Waukee FLO·METER

With the Waukee FLO-METER'S built-in Valve, you adjust the gas flow in full view of the scale. You can see what you're doing!

The Control Valve is an integral part of the FLO-METER, designed for panel mounting and simple piping. No extra valve piping or installation. Saves time and money.

It's a Waukee-designed and built valve — sturdy, simple, smooth. Needle-valve principle for accuracy, sensitivity, and easy cleaning.

And you can still clean the FLO-METER in 5 minutes *or less!*

Complete information in Bulletin 203. Write for it. Waukee Engineering Company, 5140 North 35th Street, Milwaukee 9, Wisconsin.

For measuring: air — ammonia — dissociated ammonia — argon — butane — city gas — endothermic cracked — exothermic cracked — forming gas — helium — hydrogen — natural gas — nitrogen — oxygen — propane.

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Your own records will show ISOBRITE Brighteners give longest possible life in rack or barrel plating operations.

2. BRIGHTNESS

You'll see for yourself that ISOBRITE Brighteners give a diamond-like sparkle that just can't be matched.

3. THROWING POWER

Even if your product has deep recesses, you'll get a uniform, all-over brightness that only ISOBRITE Brighteners can give you.

4. WIDER BRIGHT RANGE

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pheres, Inc. Various sized generators will produce from 250 to 5000 cfh. of 99+% purity hydrogen. The entire unit is mounted on a single base. All that is required for installation is utility connections.

For further information circle No. 435 on literature request card, page 48-B.

Calibration System

A new electronic calibration system that is completely transistorized and powered by six conventional flashlight batteries has been announced by Morehouse Machine Co. Designed for the calibration of force measurement systems, it is accurate to 0.1%, is compact and portable. In operation, the force is applied to a load ring which has a differential transformer attached to its internal bosses. Ring deflection is sensed by the differential transformer and transmitted electrically to a null-balance instrument. This displacement is balanced against another differential transformer which is connected to a micrometer dial. When a null-balance is achieved, as shown by a null-balance indicator, the micrometer dial reading is taken and translated into pounds of force.

For further information circle No. 436 on literature request card, page 48 B.

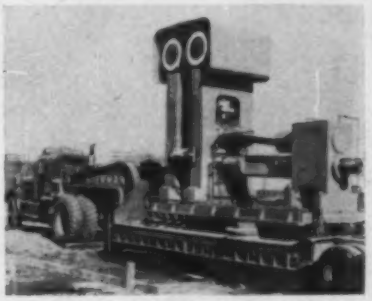
Swaged Tubing

McDanel Refractory Porcelain Co. has announced a crushable aluminum insulating tubing for swaging. It is a replacement for packed powder insulation. Swagable tubing is used for insulation in low-temperature thermocouples and heating elements. The wire and insulation are encased in metal sheaths by a swaging process. General procedure is to string crushable alumina insulators on the wire, then place insulator and wire in a close-fitting metal tube. The entire assembly is processed through the swaging machine and reduced to the desired size.

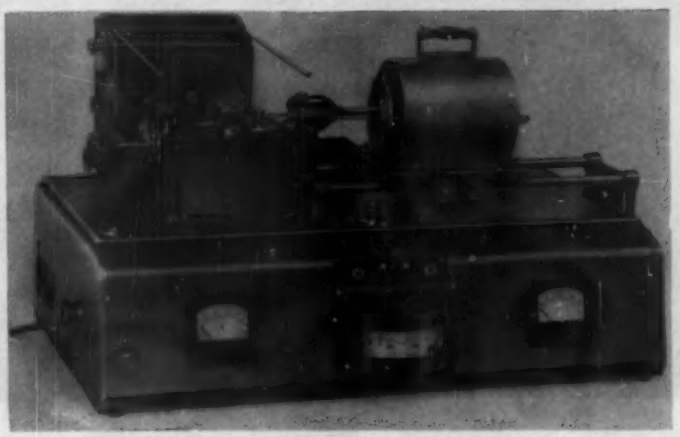
For further information circle No. 437 on literature request card, page 48-B.

Rolling Mills

The Fenn Mfg. Co. has announced a two-high breakdown mill which will be used for basic metallurgical research. The mill has 18.5 in. rolls and is equipped with electric screwdowns, internal-external cooling of the rolls, full pressurized lubrication of all bearings. The mill is 15 ft. high, nearly 8 ft. wide, 15 ft. long and weighs 65 tons. At a rolling speed of 600 fpm. it will reduce 12 in. width



DILATOMETERS
SYSTEM BRINKMANN-NETZSCH



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For **RESEARCH:** Model DA
Fully automatic with program controlled rate of heating and variable recorder speeds.
Prices from $2700.00 complete.

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Simplified dilatometer w/o automatic features, direct reading.
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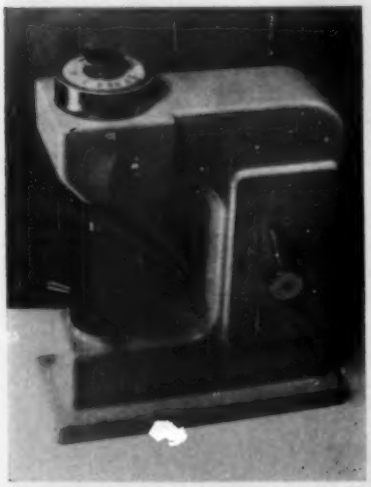
brass 0.286 in. per pass. This mill is also available as a four-high work roll driven mill and as a combination two-high/four-high rolling mill.

For further information circle No. 438 on literature request card, page 48-B.

Microhardness Testing

A new microhardness tester that supplies readings without a microscope has been announced by Newage Industries, Inc. This instrument permits fast hardness testing of watch and instrument parts, surface layers, thin materials, small wires, tips of cutting tools, wire punches and other small precision parts. A large, dial indicates hardness numbers from 100 to 1000 corresponding to diamond pyramid hardness method. The tester is available in 1 or 2 kg. loads, penetrating to 0.002 or 0.004 mm. respectively.



For further information circle No. 439 on literature request card, page 48-B.

Ultrasonic Cleaning

A new ultrasonic system has been announced by the Narda Ultrasonics Corp. The series comprises a 200 watt output ultrasonic generator and a 5-gal. tank, 14 by 10 by 9½ in., equipped with transducers. In addition to cleaning, the series 1500 can be used for metal finishing, polishing, brightening, radioactive decontamination, plating, etching, impregnating, degassing and accelerating reaction rates.

For further information circle No. 440 on literature request card, page 48-B.

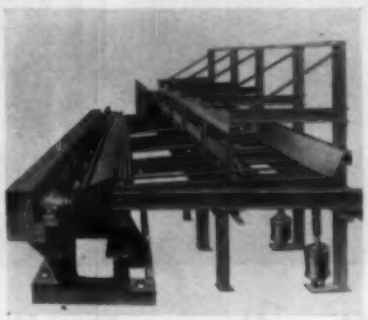
Precision Ground Steel

Vanadium-Alloys Steel Co. has announced a new product called royal precision ground low-carbon steel. It is intended for applications that do not require heat treatment other than casehardening. Royal contains about 0.18% carbon and is furnished ground to a finish of 35 micro-in. or finer. It is sold in standard 24-in. lengths packaged in rust inhibiting envelopes. It is supplied in a range of sizes from ¼ to 2⅞ in. square through flats running from 1/16 by ⅛ to 12-in. widths to 1½ by 2 to 16-in. widths.

For further information circle No. 441 on literature request card, page 48-B.

Bar and Tube Feeding

The Spurgeon Co. has announced a new automatic bar or tube feeding system. In operation, first 12,000 lb. bundles of bars are placed on a loading section. These are conveyed lengthwise to a bundle unscrambler which unbands the bundles and conveys the individual bars crosswise under a gage. A magazine of bars is built up against a stop. As they are needed an escapement automatically pushes one bar at a time to the top of an incline where it feeds on a roll conveyor carrying it to a shear, cut-off, press or other machine. It is adaptable to electronic control.



For further information circle No. 442 on literature request card, page 48-B.

Plastic Coating

Metal & Thermit Corp. has announced a new spray-applied vinyl textured finish that looks like leather. It is applied with an ordinary paint spray gun. The choice of colors is unlimited. The surface can be varied to produce either shallow or deep texture. When desired, a smooth coating can be produced. Film thickness

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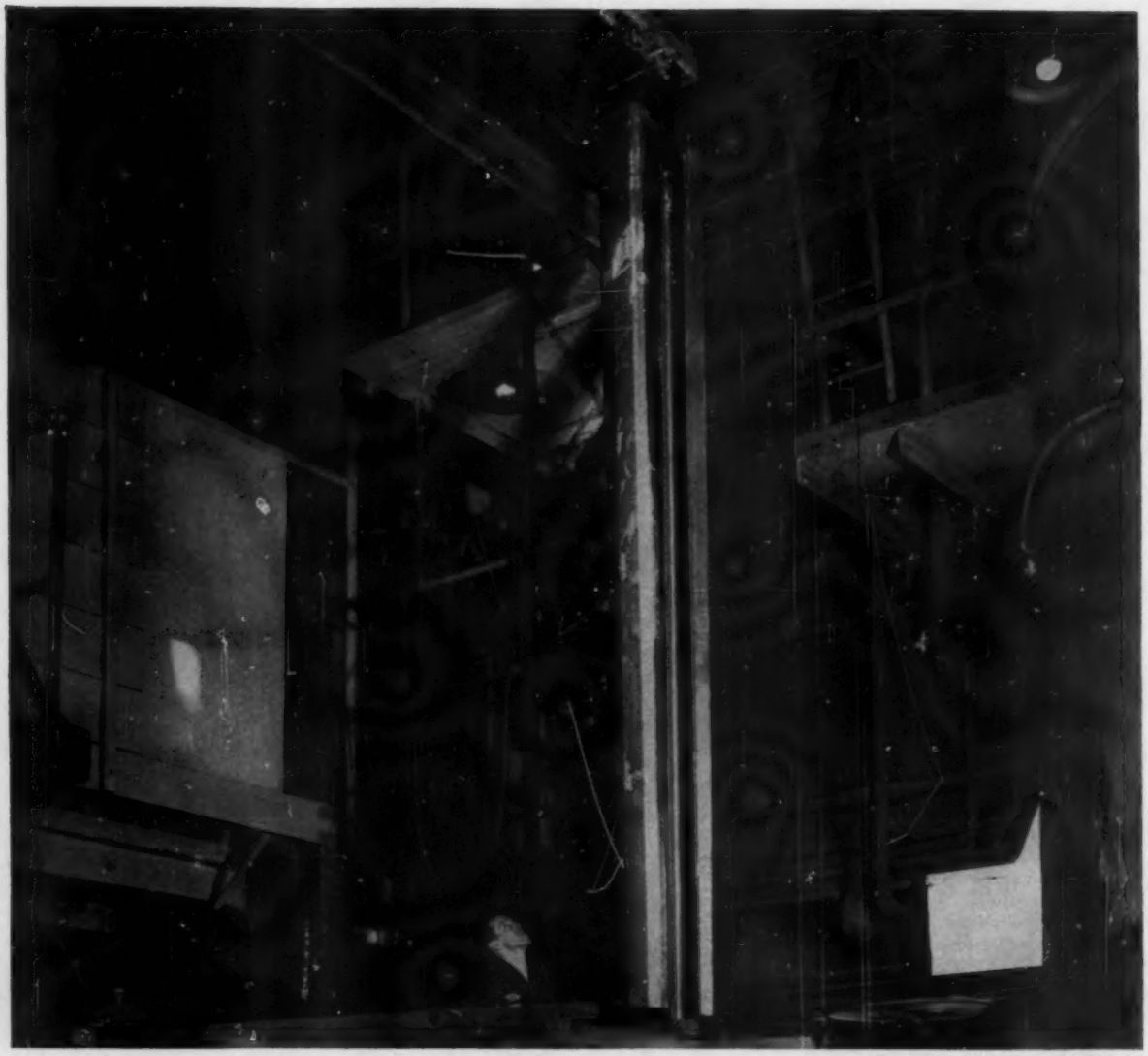

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Steam-catapult rails for aircraft carriers *have* to be straight and perfectly hardened.

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Industrial Products Department

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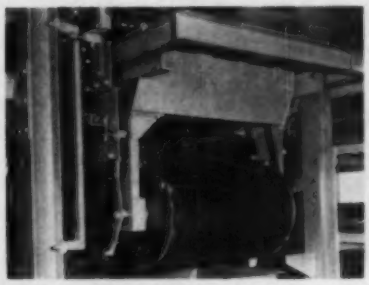
114 East 32nd Street
New York 16, N. Y.

can be varied from 6 to 40 mils or more depending on the number of coats applied.

For further information circle No. 443 on literature request card, page 48-B.

Processing Barrel

A new processing barrel with a door that opens and closes automatically has been announced by Hanson-Van Winkle-Munning Co. The barrel is designed for cleaning, phosphating, blackening, chromate treatments, pickling and similar processing. After the barrel is loaded, a signal starts



it rotating. Rotation actuates the mechanism that closes the door, which is held secure by a detent spring while the barrel passes through the treatment cycle. On completion of the treatment, barrel rotation is reversed to open the door and discharge the load.

For further information circle No. 444 on literature request card, page 48-B.

Vacuum Furnace

General Vacuum Corp. has announced a new compact Globar-heated horizontal vacuum furnace for laboratory and limited production applications. It features a uniform horizontal hot zone, 6 in. I.D. by 12 in.

long, special alloy retort and heating elements for operation up to 2200° F. and 4-in. vacuum pumping system with 720 cfm. capacity at 1×10^{-4} mm.

For further information circle No. 445 on literature request card, page 48-B.

STRAITS TIN REPORT

New developments in the production, marketing and uses of tin

MALAYAN TIN BUREAU

Tin becomes gold . . . when alloyed with copper to produce a 24-kt. gold brilliance for attractive decorative finishes. The ratio of tin to copper is 12% to 88%. When the tin content is increased to 20%, the alloy takes on a pale yellow hue. Tin-bronze is reported to eliminate the usual alloy plating difficulties. It is as easy to control as single m tal deposition.

★

Superior to nickel plate in hardness and abrasion resistance—that is how the product of a new, highly decorative electroplating process is described. The new plating, successfully used for several metals, is a 50-50 tin-copper alloy. It maintains its original color up to its own melting point.

★

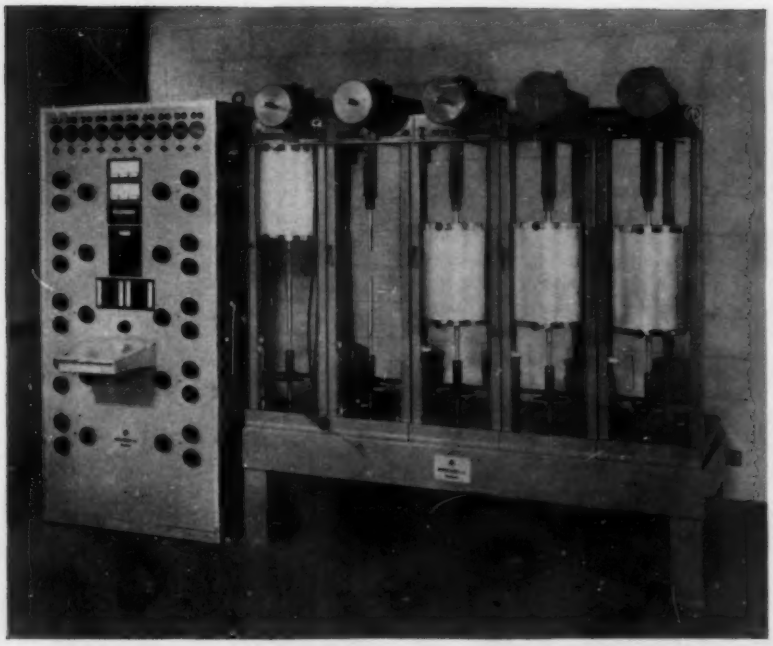
Exceptional resistance to salt spray dictated approval by the U.S. Navy's Bureau of Aeronautics of an electrodeposited cadmium-tin alloy . . . 75% cadmium, 25% tin. This rugged alloy protects Navy hydroplane engines from the corrosive action of salt water.

★

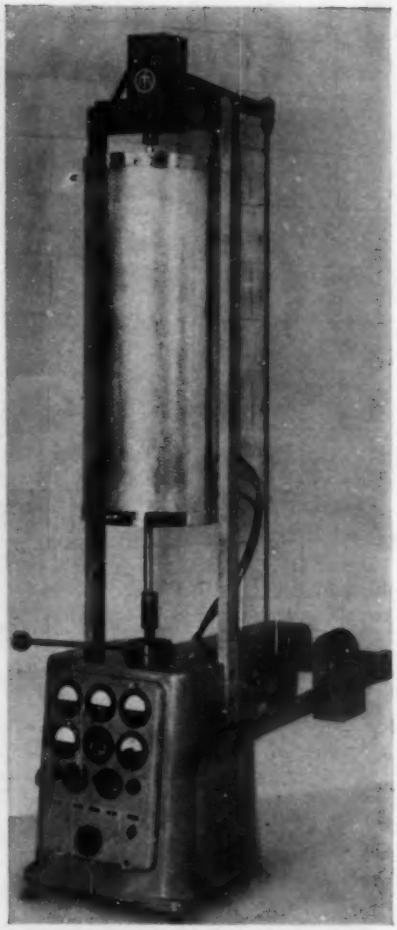
Tin is tough. That is why a plating of tin is commonly applied to automotive pistons. It prevents damaging scuffing during engine break-in. The plating serves as a protective lubricant.

Ask us to send you TIN NEWS, a monthly letter. It will keep you posted on tin supply, prices, new uses and applications.

The Malayan Tin Bureau
Dept. 25J, 1028 Connecticut Ave., Washington 6, D.C.



Above: The control cabinet shown has regulating and measuring equipment suitable for 10 furnaces. The furnaces are independent from one another. Equipment of this type is desirable for research and original explorations.



Ten samples strung end to end are accommodated by this tester. Its low cost per specimen makes large volume routine testing possible.

MOHR & FEDERHAFF

Creep Strain Testers

SINGLE SAMPLE OR MULTIPLE SAMPLE

Creep testing has in many instances progressed from an experimental to a routine basis in the past few years. The physical properties of a steel which is to be used at normal temperatures can be determined by a simple test, because the properties of steels do not change with time at ordinary temperatures. However, the designers now want materials which will endure high temperatures under load for long time periods. Such materials are needed to obtain greater efficiency in modern and future engines, turbines and other machinery. We have the problem of testing many possible materials at many possible loads at many different temperatures over many different time periods. The question arises—Is it possible to test for a short period, say 48 hours and extrapolate the results for longer times? Unfortunately, in most cases the answer is no, if temperatures over about 400° C. (720° F.) are under consideration. Test periods of 1,000 to 10,000 hours are common and tests up to 100,000 hours (over 10 years) are being carried out.

It is obvious that a large number of single sample testers would be required for a long term test program on even a few steels.

Mohr & Federhaff, in cooperation with some of the most advanced creep test laboratories in Europe, have arrived at the following solution: A few individual or battery type testers for individual samples should be used for research and experimental work with the balance of the long term testing being handled by multiple testers accommodating 10 samples fastened end to end in one furnace and loading system. This has made large scale testing possible.

We believe an examination of the problem indicates that the combination of a few single unit creep testers with several multiple testers affords the most satisfactory means of obtaining voluminous creep data.

A COMPLETE LINE OF TESTING MACHINES FOR TENSION, COMPRESSION, BENDING, CUPPING, HARDNESS, CREEP, TORSION, DROP, CALIBRATION, MEASURING AND SPECIAL PURPOSE TESTS.

Adolph I. Buehler Inc. OPTICAL & TESTING EQUIPMENT

2120 GREENWOOD ST. EVANSTON, ILLINOIS, U. S. A.

Shown is a Drever Gas-Fired Strip Belt Conveyor Furnace for reducing and drying copper powder at the rate of 10 tons per 24 hours at 1000°F.

In the foreground is a Drever Inert Gas Generator for supplying the necessary gases to purge the furnace entry and exit areas.

CONTINUOUS REDUCTION AND DRYING FURNACES

for metal powders

In the manufacture of metal powders, an essential step is the ability of a furnace to completely reduce and dry metal powders and obtain powder of uniform particle density. Experience proves Drever Strip Belt Conveyor Furnaces meet these rigid specifications.

Completely integrated sheet belt furnaces are available for treating oxides of nickel, iron, copper and tungsten. Powder is received from a hopper, leveled on belt and conveyed through a highly reducing atmosphere in the heating and cooling chambers.

Specially designed roll seals keep furnace openings tight while the areas are purged with inert gas. Complete temperature control as well as product uniformity is inherent in the design of these furnaces. They are available for fuel firing, radiant tube or electric heating.

DREVER COMPANY

RED LION ROAD and PHILMONT AVE.
BETHAYRES, PA.

XXVIII

This is the twenty-eighth of a series of advertisements dealing with basic facts about alloy steels. Though much of the information is elementary, we believe it will be of interest to many in this field, including men of broad experience who may find it useful to review fundamentals from time to time.

Cold-Finishing of Alloy Steel Bars: Turning and Polishing

Continuing our discussion of the cold-finishing of alloy steel bars, we take up the subject of turning and polishing. A later discussion will cover grinding and polishing. Both require removal of surface metal. In both the turning and grinding operations, adequate allowances provide for the removal of decarburization and surface defects which sometimes occur in alloy bars.

As previously stated, the outstanding advantage of cold-drawn bars over hot-rolled bars is the *bright, smooth finish*. However, the quality of the cold-drawn finish varies with the size and amount of draft (reduction of cross-sectional area) applied in cold-drawing. For example, by using a 1/16-in. draft, a 3/4-in. round would have a better cold-drawn finish than a 3-in. round.

When a superior mirror-like finish with additional accuracy is required on surfaces that are not machined (such as on shafting or machine parts), two processes other than cold-drawing are suggested: turning and polishing, and grinding and polishing. The first of these will be discussed here.

Turning and Polishing. This method of cold-finishing is generally associated with centerless bar-turners, accommodating rounds from 1 1/4-in. to 6-in. diam, inclusive. The process is the reverse of conventional lathe-turning, which is normally used for larger sizes. The centerless turning equipment uses two cutter heads which contain from one to four cutting tools. The system provides for both rough and finish cuts. The bar, which is stationary, is fed horizontally into the rotary cutter heads by means of a mechanical or hydraulic feeding mechanism. Most bar-turners are equipped with a series of polishing rolls that also rotate around the bar as it feeds from the rotary cutter heads. This, combined with subsequent burnishing action from the straightening rolls, imparts a high degree of polished finish to the product. A polished surface on a turned bar can also be produced by a number of passes through the straightening rolls.

This process is applicable to normalized, annealed, or heat-treated carbon and alloy bars. It does not materially affect the mechanical properties. For this reason, the end product can be machined unsymmetrically, with little or no tendency to warp.

Bethlehem metallurgists will gladly work out any problem in the cold-finishing of alloy steel bars. Always feel free to ask for their services.

When you are in need of steels remember, too, that Bethlehem manufactures the entire range of AISI standard alloy grades, as well as special analysis steels and all carbon grades.

If you would like reprints of this series of advertisements, please write to us, addressing your request to Publications Department, Bethlehem Steel Company, Bethlehem, Pa. The subjects in the series are now available in a handy 40-page booklet, and we shall be glad to send you a free copy.

BETHLEHEM STEEL COMPANY
BETHLEHEM, PA.

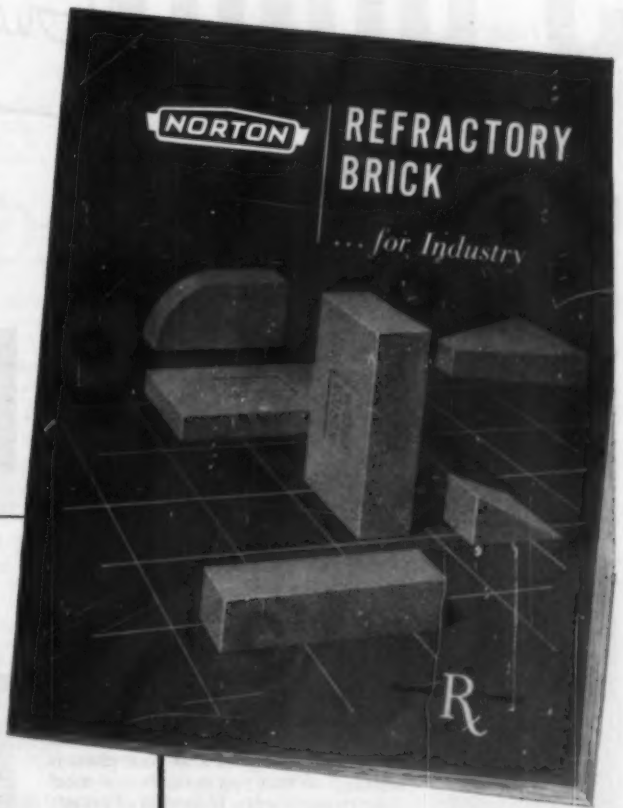
On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation. *Export Distributor:* Bethlehem Steel Export Corporation

BETHLEHEM STEEL

BETHLEHEM STEEL

Send for this

New Booklet to Help Improve Your High Temperature Processing



Covers Norton refractory brick applications, characteristics, chemical analyses — includes helpful data on materials of construction for temperatures up to 4,400°F.

This new, 24-page Norton booklet can be a dependable guidebook for your selection of the refractories you need to improve production and cut costs in high temperature processing.

Eight Norton-developed refractory materials are covered: ALUNDUM* "T" 87% Alumina; ALUNDUM "A" 99% Alumina; ALUNDUM "L" 99% Insulating Alumina; CRYSTOLON* "G" Silicon Carbide; CRYSTOLON "N" Nitride Bonded Silicon Carbide; MAGNORITE* "K" Fused Magnesia; Zirconia "H" Dense Zirconia; Zirconia "I" Insulating Zirconia.

All essential details are listed, such as: how each material is produced . . . important properties, characteristics and chemical analyses . . . shapes of brick and other molded products that are available . . . representative applications . . . packing methods that assure safe arrival.

Also included are charts and tables of brick shapes and sizes, thermal expansion and conductivity graphs, and a temperature conversion chart.

Norton refractories — engineered and prescribed for the widest range of applications — have helped many users save time and money. The R's described in "*Norton Refractory Brick . . . for Industry*" may do the same for you. Write for your copy to NORTON COMPANY, Refractories Division, 328 New Bond Street, Worcester 6, Massachusetts.

NORTON
REFRACTORIES
Engineered... ℞ ...Prescribed
Making better products . . . to make your products better

*Trade-Marks Reg. U. S. Pat. Off. and Foreign Countries

NORTON PRODUCTS Abrasives • Grinding Wheels • Grinding Machines • Refractories • Electrochemicals — **BEAN-MANNING DIVISION** Coated Abrasives • Sharpening Stones • Pressure-Sensitive Tapes

C. I. HAYES SELLS MORE THAN JUST HEAT TREATING EQUIPMENT
. . . WE SELL LONG-TERM CUSTOMER SATISFACTION – WITH THE

5-point *Results Guaranteed* plan!

1 DETERMINE BEST PROCEDURE . . .

The Hayes Laboratory is unique . . . it allows you to take an active part . . . see the actual results . . . of procedures and operations developed to suit your specific needs. Hayes laboratory facilities . . . and the services of our entire staff . . . are available during this vital phase . . . WITHOUT COST OR OBLIGATION. Step 1 to RESULTS GUARANTEED!

2 SELECT RIGHT EQUIPMENT . . .

Your customized procedures are developed on an extensive line of full-scale *production* heat treating equipment . . . not laboratory models. The equipment that goes into your plant is identical to that you *actually saw* meet your requirements. If models of proper size are not available, equipment will be tailored to your exact needs. Step 2 to RESULTS GUARANTEED!

3 START-UP AND INSTRUCTIONS

Free start-up service by a Hayes engineer completely familiar with the procedure developed assures duplication of laboratory results. Your staff is fully instructed on how to make the operation most economical and how to maintain the equipment for maximum life. Step 3 to RESULTS GUARANTEED!

4 PROPER SERVICING . . .

Hayes is known for its prompt, competent service . . . well aware that heat treating equipment is production equipment and that downtime is costly to the customer. Hayes maintains a private plane that speeds its Service Engineers to you when needed. Hayes is just as concerned about your equipment *after* you buy it as *before* you buy it. Step 4 to RESULTS GUARANTEED!

5 MAINTAINING OPTIMUM OPERATION . . .

Hayes maintains an extensive inventory of stock parts . . . your assurance that the equipment can be maintained in optimum operating condition long after competitive equipment has become obsolete or worn out. Because highest quality materials are used, less frequent rebuilds are required. Relatively few Hayes furnaces appear on the used-furnace market . . . proof that customers buy 'em, like 'em, hang on to 'em! Step 5 to RESULTS GUARANTEED!

Solve your heat treating problems the RESULTS GUARANTEED way! Request bulletins for complete data on any of the famous C. I. Hayes CERTAIN CURTAIN electric furnace line.

ELECTRIC CERTAIN CURTAIN FURNACES

FREE LITERATURE: Please send data on equipment for procedures checked.

- ☐ High Speed Hardening
- ☐ Tool Steel Hardening
- ☐ Carbo-Nitriding
- ☐ Tempering
- ☐ Vacuum Heat Treating
- ☐ Bright Heat Treating
- ☐ Stainless Steel Heat Treating
- ☐ Sintering
- ☐ Copper Brazing and Soldering
- ☐ Lead Pot Hardening and Tempering
- ☐ Atmosphere Generation
- ☐ Gas Drying
- ☐ Other

C. I. HAYES, INC.
802 WELLINGTON AVE., CRANSTON 10, R. I.

Name.....*Title*.....
Company.....
Street.....
City.....*State*.....

APPLICATION and EQUIPMENT new literature

447. Abrasive Cleaning
Folder on Malleabrasive for airless blast cleaning equipment gives advantages, grades, equipment it can be used with and parts that can be cleaned. *Globe Steel Abrasive*

448. Abrasive Cleaning
Catalog 57-WX on brush types, sizes, speeds, filaments. Aids to power brush selection. *Pittsburgh Plate Glass*

449. Air Washers
Bulletin No. 256 on acid-proof air washers for ventilation systems. Construction and accessories. *Automotive Rubber*

450. Alloy Castings
8-page bulletin on alloy castings for heat treating. *Ohio Steel Foundry*

451. Alloy Steel Castings
Specifications for T-loy 34 and T-loy 42. Heat treatment and characteristics. *Unitcast Corp.*

452. Aluminum Die Castings
Bulletin on design and manufacture of aluminum die castings. *Hoover Co.*

453. Aluminum Extrusions
Folder lists alloys used, finishes, trade phraseology. *General Extrusions*

454. Ammonia
New 6 and 4-page bulletins on ammonia storage units and nitrogen generator. *Hamler Industries, Inc.*

455. Ammonia
New 69-page data book on anhydrous ammonia and ammonia liquor. Chemical and physical properties, specifications, analytical procedures, bibliography, *Nitrogen Div.*

456. Annealing
4-page reprint No. 62 on salt bath annealing of cold finished sections. *Ajax Electric*

457. Atmosphere Furnace
New 12-page Bulletin 850.20 on controlled atmosphere reciprocating hearth furnace for continuous hardening, light case carburizing, Ni-Carb ammonia-gas carburizing and other heat treating processes. *American Gas Furnace*

458. Atmosphere Generators
New 4-page bulletin I-457 includes flow charts and cost analyses of inert gas system. *Gas Atmospheres*

459. Barrel Finishing
New 8-page Bulletin No. 158 on equipment for precision barrel finishing. *Lord Chemical Corp.*

460. Blast Cleaning
Bulletin 227 on airless blast cleaning machine. Features of construction, sizes, how it operates. *Pangborn*

461. Brazing
Brazing News No. 78 tells of silver brazing's characteristics. Case histories. *Handy & Harman*

462. Calibration
New Bulletin 159 on proving rings in weighing and force measuring systems. Their uses, construction and operation. *Morehouse Machine*

463. Carbides
76-page catalog 56-G of sintered carbides, hot pressed carbides, cutting tools, drawing dies, wear resistant parts. *Metal Carbides*

464. Carburizing Steels
12-page reprint on making gears of new carburizing steels. *Climax Molybdenum*

465. Chromate Finishing
File on chromate conversion coatings for prevention of corrosion and paint-base treatment of nonferrous metals. *Allied Research Products*

466. Cleaning
Bulletin No. 72 gives reagents and procedure for acid acceptance test for trichlorethylene. *Hooker Electrochemical*

467. Coated Metals
New bulletin on roll coating shows how it is done and includes samples. *Roll Coater, Inc.*

468. Coatings
20-page bulletin on chemical conversion coatings. How and where each is used. Blackening process. *E. F. Houghton*

469. Cold Finished Steel
16-page booklet on 10 grades of cold finished steels. Analysis, machinability, heat treatment, wear resistance. *Jones & Laughlin*

470. Cold Rolling
Description of advantages of cold rolling of ship propeller shafting. How it is done. *Erie Forge & Steel*

471. Compressors
12-page Bulletin 126-A on application of turbo compressors to oil and gas-fired equipment used in heat treating, agitation, cooling, drying. Performance curves, capacities. *Spencer Turbine*

472. Controlled Atmospheres
Bulletin 753 on generator for atmospheres for hardening, brazing, sintering and annealing carbon steels. *Hevi Duty*

473. Controlled Atmospheres
New Bulletin No. 2051 on Dewpointer. Models, specifications, principle of operation, applications. *Illinois Testing Lab.*

474. Copper Alloys
16-page publication E-5 on physical properties and applications of high-strength, corrosion-resistant copper alloys. *American Brass Co.*

475. Creep Testers
Data file lists 8 models, gives salient features and illustrates them and uses. *Arcweld Mfg.*

476. Cutting Torch
Memco News, June-July 1958, gives data on cutting, gouging, beveling, grooving torch. Various models, uses, power sources, case histories. *Miller Electric Mfg. Co.*

477. Deep Drawing
Brochure on hydroforming discusses parts that can be made and costs of tooling for different shaped parts. *Hydroforming Co. of America*

478. Degreasers
Folder on vapor and solvent degreasers describes equipment and advantages. *Randall Mfg.*

446. Stainless Steel
The use of stainless steel in the chemical industry is the subject of this revised 40-page booklet. After a general discussion, its uses in the manufacture of acids and other chemicals, plastics, synthetic detergents, pharmaceuticals, dyes, soaps and in the petrochemical industry are discussed with flow charts

showing just where stainless is considered indispensible. A table of chemical compositions and properties of various grades of stainless steel is included, as well as a table of corrosion resistance of four representative types in various mediums. *Allegheny Ludlum Steel Corp.*

479. Descaling Process
8-page bulletin on sodium hydride descaling process for ferrous and nonferrous metals. *DuPont*

480. Electric Furnaces
8-page Bulletin 570 on heat treating, melting, metallurgical tube, research and sintering furnaces. Custom designs for special requirements. *Pereny*

481. Electric Furnaces
12-page bulletin on furnaces for hardening high-speed steel. Diamond block method of atmospheric control. *Sentry*

482. Electrodes
New 12-page Bulletin No. MW-222 on hard surfacing electrodes and wire. Check-list of uses on more than 400 types of welding equipment. *A. O. Smith Corp.*

ACHESON

dispersions digest

Reporting uses for

dag® BRAND DISPERSIONS

COLLOIDAL GRAPHITE, MOLY-SULFIDE, VERMICULITE, AND OTHER SOLIDS

COLLOIDAL GRAPHITE PROVES IDEAL AS FORGING LUBRICANT

Lubricants to be suitable for use on forging dies for steel and nonferrous metals must be stable under the high temperatures and pressures involved. Besides providing the most effective lubrication for hot-work dies, 'dag' brand dispersions act as coolants. Total advantages gained by using Acheson colloidal graphite, as described in the following applications are: improved quality of the forging, reduced die wear, lower production costs, and improved working conditions.

'dag' dispersion improves quality, cuts costs for Utica Drop Forge and Tool Division. With a large share of their capacity being devoted to the forging of jet engine blades, Utica finds it must maintain high production, consistently high quality, and a competitive price. Blade-forging dies have a comparatively short life due to rapid wear caused by the thinness of the blades, the high pressures required to form the heat-resistant alloys used, and the closer tolerances required. They have found that *every one* of these requirements can be met by using 'dag' colloidal graphite dispersed in water as their forging lubricant. First, it must withstand temperatures which range from 1950-2200° F. Sprayed on both halves of the die it forms a tightly adhering, smooth, microscopically-thin film that aids metal flow and substantially protects the die itself. In many cases, this has meant fewer finishing operations and therefore higher production, due to the improved quality of the blades. A compressor blade formerly required four blows from upset to finish, with an intermediate heat and tumbling operation. Now, this operation is done in only two blows from original heat. The savings . . . $16,000 a year on this part alone! Add increased life of these precision dies and you can appreciate what a 'dag' colloidal graphite dispersion means to efficient forging. Utica finds water-based dispersions best for press forging, and colloidal graphite in oil the best lubricant for hammers.

Operator spraying colloidal graphite on both top and bottom die halves before forging jet engine blades at Utica Drop Forge and Tool Division, Kelsey-Hayes Company.

Concentrated Acheson colloidal graphite being applied to die surfaces before they are put in service.

Pre-treatment and operational use of 'Aquadag' greatly increases die life. Before putting dies into service, a prominent midwestern manufacturer finds that by preheating them to about 250° F. and brushing on a dispersion of colloidal graphite in water, they have generally *doubled* the working life of their dies. When used as an operational lubricant, die wear on a truck body brace die was proved by actual measurements to be only *one-third* the former rate. And this was with 'Aquadag' diluted 1 to 240 in water! . . . Ample proof of the wide coverage, film toughness, lubricity, and basic economy of a "dag' brand dispersion.

Colloidal graphite is resistant to heat, does not react with the die steel, and the extremely small particle size permits an actual adsorption to the metal surface. A water carrier eliminates the usual smoke and fumes thus affording better working conditions and keeping die temperatures down. After the carrier evaporates, a dry graphite film remains which, besides being an efficient lubricant, protects the die from the accumulation of abrasive dust and scale. Die life is extended from 8 to 14 days and production increased by the reduction in downtime.

Specially compounded, ready-to-use forging lubricants containing 'dag' colloidal graphite are available from industrial lubricant suppliers. If you have a forging lubrication problem, it may pay you to call in your Acheson Service Engineer.

Write for additional information contained in Acheson Bulletin No. 426. Address Dept. MP-98.

ACHESON *Colloids Company*

PORT HURON, MICHIGAN

A division of Acheson Industries, Inc.

Also Acheson Industries (Europe) Ltd. and affiliates, London, England

50th

Offices in: Boston • Chicago • Cleveland • Dayton • Detroit • Los Angeles • Milwaukee
New York • Philadelphia • Pittsburgh • Rochester • St. Louis • Toronto

483. Electron Microscope
24-page booklet on use of electron microscope in science and industry. *RCA*

484. Electroplating
Bulletin on electroplating lists key characteristics of 16 processes. *Hanson-Van Winkle-Munning*

485. Electroplating
Bulletins on electroplated gold, rhodium, palladium, platinum, silver, nickel, and analysis of gold and gold alloy solutions. *Technic*

486. Extrusions
Bulletin on extruded seamless alloy and stainless steel tubing. Properties, shapes. *Metals Processing Div., Curtiss-Wright*

487. Extrusions
New booklet describes advantages of Cold-Prest impact extrusions, design considerations and methods of production. Alloys used. *Mueller Brass Co.*

488. Finishing
New bulletin on Unichrome coating 6400, a vinyl coating with the appearance of leather. Coating procedure. Advantages. *Metal & Thermit*

489. Finishing Systems
New 12-page brochure on industrial finishing systems. Engineering, fabricating, installing. *Granco, Inc.*

490. Flaw Location
4-page folder on dye penetrant method of flaw location. Pre-cleaning, applying penetrant, removing excess penetrant, applying developer and interpreting results are discussed. *Turco*

491. Forgings
8-page bulletin on typical upset forgings. Advantages and metal saved. *Champion Rivet*

492. Forgings
12-page booklet on how forged weldless rings and flanges are made. Case histories. *Standard Steel Works Div., B-L-H*

493. Forgings
Bulletin on forge steelmaking, open die forging, machining, heat treating and finishing. *National Forge*

494. Formed Plate
Bulletin on stainless steel ASME and standard flanged and dished heads. 352 available dies listed. *G. O. Carlson*

495. Formed Shapes
26-page catalog No. 1555 contains drawings and dimensions of more than 100 shapes. *Roll Formed Products Co.*

496. Furnace Belts
42-page booklet on alloy steel belts for continuous high-temperature furnaces. Belt selection guide. *Wickwire Spencer*

497. Furnace Brazing
Folder gives correct procedures for furnace brazing. Design for furnace brazing, brazing materials, atmospheres. *American Platinum*

498. Furnace Charging
12-page brochure on eight models of charging machines for heating and melting furnaces. *Salem-Brosius*

499. Furnace Fixtures
16-page catalog on baskets, trays, fixtures and carburizing boxes for heat treating. 66 designs. *Stanwood*

500. Furnaces
16-page bulletin 135 on industrial furnaces and atmosphere generators. Continuous systems. *Continental Industrial Engineers*

501. Furnaces
6-page folder on gas-fired, oil-fired and electric furnaces. Typical installations. *Electric Furnace Co.*

502. Furnaces
New Bulletin 5711-A on conveyor furnaces for operation to 2100° F. Specifications. *C. I. Hayes, Inc.*

503. Furnaces
Catalog on standard and special furnaces and ovens to 3000° F. *L & L Mfg.*

504. Furnaces
New 12-page catalog on electric heat treating furnaces. Data on each of 57 models. Controls, instruments, elements and accessories. *Lucifer Furnaces, Inc.*

505. Furnaces
Lists of surplus furnaces for sale. *Joe Martin Co.*

506. Furnaces
Monthly bulletin on used equipment. *Metal Treating Equipment Exchange*

507. Furnaces
Folder describes complete set up for heat treatment of small tools, including draw furnace, quench tank and high temperature furnace. *Waltz Furnace*

508. Gas Analysis
Bulletin 482 on gas chromatograph for analysis of gases and low-boiling liquids. How it works. *Harshaw Scientific*

509. Hardness Tester
New Bulletin F-1689-3 on Impressor portable hardness tester for aluminum, aluminum alloys and soft metals. *Barber-Colman Co.*

510. Hardness Tester
20-page book on hardness testing by Rockwell method. *Clark Instrument*

511. Hardness Tester
Bulletin A-16 on micro-reflex hardness testers. Loads to 3000 gr. Zeiss optical system. *Gries Industries, Inc.*

512. Hardness Tester
4-page bulletin on portable metal hardness tester for any shape or metal. Ranges, features. *Newage Industries*

513. Hardness Tester
Catalog 72-1 on Leitz miniload tester for Vickers and Knoop hardness tests. *Opto-Metric Tools, Inc.*

514. Hardness Tester
13-page booklet on microhardness tester with optional Vickers or Knoop diamond. *Geo. Scherr*

515. Hardness Tester
Data on hardness testing scleroscope with equivalent Brinell and Rockwell C numbers. *Shore Instrument*

516. Hardness Tester
Catalog of testers for normal hardness, superficial testing, accessory and special testing and micro and macro hardness testing. *Wilson Mechanical Instrument*

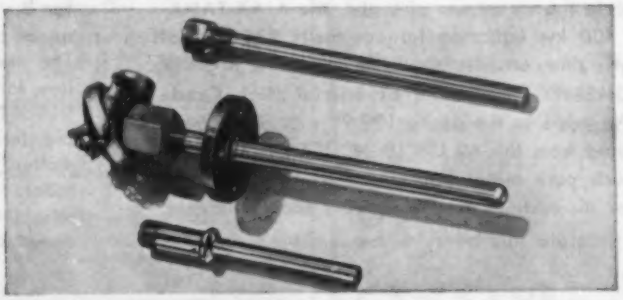
517. Heat-Resistant Castings
16-page bulletin on design, foundry practice and applications. *Electro-Alloys*

518. Heat Treating
20-page catalog on the Homocarb method with Microcarb atmosphere control for heat treatment of steel. *Leeds & Northrup*

519. Heat Treating Belts
New 12-page catalog of conveyor belts and data for their design, application and selection. *Ashworth Bros.*

520. Heat Treating Equipment
New 24-page Catalog 54 on light-weight processing and heat treating equipment. *Pressed Steel Co.*

521. Heat Treating Fixtures
32-page catalog G-10A lists process



Complete Range Of

Thermocouple Assemblies

With T-E's thermocouple assemblies you get: (1) choice of an extremely wide variety; (2) carefully pre-tested quality; (3) simplified ordering – one code number for a complete thermocouple assembly.

Thermocouples – Wire type from 20 to 6 gage. Ruggedly constructed, sensitive in performance. Available with fiberglass or various types of ceramic bead insulation. Calibrated in Iron-Constantan, Copper-Constantan or Chromel-Alumel.

Connection Heads – Choice of various connection heads – heavy duty, lightweight, weatherproof, etc. Available with nipples and unions in a variety of sizes and lengths.

Thermowells – Bar stock or built-up, straight or tapered, with threaded, flanged or ground-joint mountings. Available in all commercial materials for all applications.

Write For Thermocouple Catalog Section H.

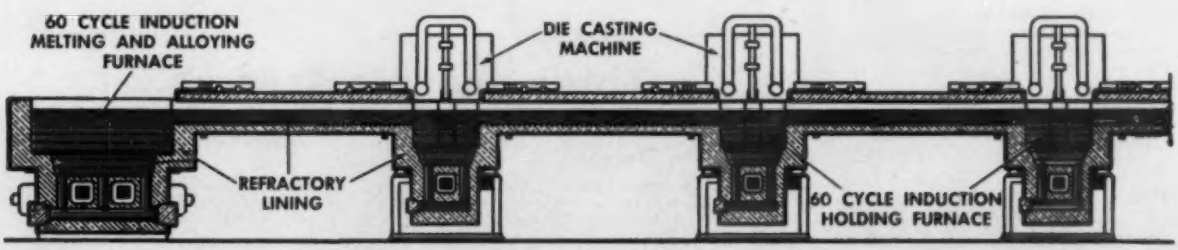
Thermo Electric Co. Inc.
SADDLE BROOK, NEW JERSEY
In Canada—THERMO ELECTRIC (Canada) Ltd., Brampton, Ont.

Birthplace of an Automotive Part

BUNKER HILL SPECIAL HIGH GRADE ZINC SLAB PRODUCED IN THE AJAX FURNACE

High in the mountains of Idaho, the AJAX-TAMA-WYATT 800 kw induction furnace melts 235 tons of electrolytic zinc cathodes day after day. THE BUNKER HILL COMPANY, originators of Special High Grade Zinc, take pride in the purity (99.99+ % Zn) of the slab poured from this 60 CYCLE INDUCTION MELTING unit. Such pure metal insures the soundness of the many zinc die castings used in our cars and appliances.

To maintain this purity when remelting the slab for die casting, hundreds of AJAX-TAMA-WYATT furnaces are used today in our busy industrial regions. The diagram below shows a modern zinc die casting line for automotive parts, using a central 60 CYCLE INDUCTION MELTING and alloying furnace, and holding furnaces at each machine. Connecting electric molten metal runways eliminate all metal transfer labor. Unexcelled metal quality, low metal losses, reliability and economy of operation are assured by using 60 CYCLE INDUCTION MELTING throughout.


60 CYCLE INDUCTION MELTING AND ALLOYING FURNACE
DIE CASTING MACHINE
REFRACTORY LINING
60 CYCLE INDUCTION HOLDING FURNACE

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ENGINEERING CORPORATION

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- TEMPER... ALLOYS
- WORKING PROPERTIES
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This booklet is available for use as a reference and buyer's guide to those sending requests on company letterheads to Dept. 7, Precision Tube Company, North Wales, Pa.

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equipment, heavy welded fabrications, muffles, trays, fixtures for furnaces, heat treating equipment, pickling equipment. *Rolock*

522. Heat Treating Fixtures
New 16-page Catalog M-7 on heat treating and corrosion resistant alloy fabrications. *Wiretex Mfg. Co.*

523. Heat Treating Furnaces
12-page booklet on various heat treating furnaces contains chronology of advances. *Holcroft*

524. Heat Treating Furnaces
Folder on industrial furnaces. Continuous designs. Insulation. *Pacific Industrial*

525. Heat Treat Pots
Catalog on pressed steel pots for lead, salt, cyanide, oil tempering and metal melting. *Eclipse Industrial Combustion*

526. Heat Treatment
Heat Treat Review, Vol. 9, No. 1, contains article on continuous strip heat treatment. *Surface Combustion*

527. Heaters
Bulletin on immersion heaters for electroplating solutions. *Glo-Quartz*

528. Heating Elements
12-page bulletin gives typical applications of silicon carbide heating elements. Hints on handling, unpacking, storage, installation, replacement. *Globar Div., Carborundum*

529. Heating Elements
24-page booklet on elements for electric furnaces and kilns includes technical data, uses, physical and electrical specifications. *Norton*

530. High-Alloy Castings
16-page bulletin, No. 3354-G, gives engineering data concerning castings used for resisting high temperatures, corrosion and abrasion. *Duraloy Co.*

531. High-Strength Steel
48-page book on T-1 steel, its properties and applications. *U.S. Steel*

532. High-Strength Steels
29-page discussion of progress being made toward higher strength alloy steels. Methods which increase strength of nickel-chromium-molybdeum alloy steel. *International Nickel*

533. High-Strength Steels
New folder on manganese-copper steels. Properties, fabricating practice. *Republic Steel*

534. High-Temperature Alloy
New 28-page book on Hastelloy X, nickel-base alloy. Property data, welding, machining, forging. *Haynes Stellite*

535. High-Temperature Alloys
Booklet "Keep Operating Costs Down When Temperatures Go Up." *International Nickel*

536. High-Tensile Steel
8-page bulletin on properties and composition of N-A-X high-tensile steel. Examples of resistance to impact, fatigue, abrasion and corrosion. *Great Lakes Steel*

537. Identifying Stainless
Cardboard chart outlining systematic method for rapid identification of unknown or mixed stocks of stainless steels. *Carpenter Steel.*

538. Induction Heating
8-page bulletin on high-frequency motor-generator sets for induction heating. *Ohio Crankshaft*

539. Induction Heating
Brochure on induction heating furnace. Frequency chart. *Pittsburgh Induction Heating Co.*

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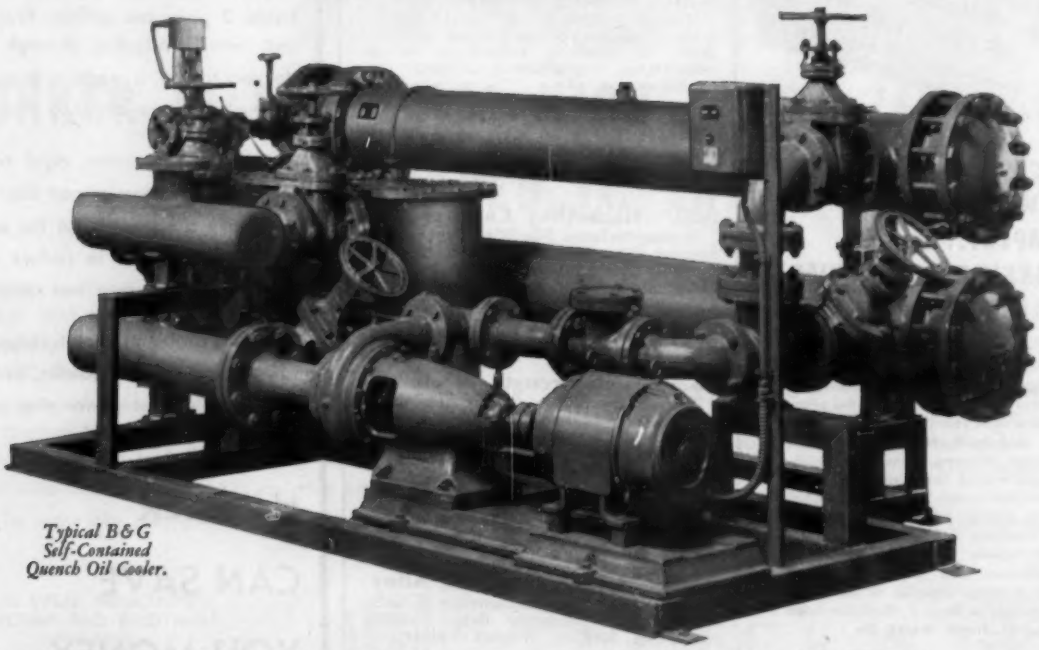

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B&G *Hydro-Flo* Oil Quenching Systems have demonstrated ability to maintain desired characteristics in the finished product. Heated metal is brought down from furnace temperature to the correct end degree with unfailing accuracy. Each batch is quenched under *identical* conditions, hence is *identical* in quality.

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540. Induction Melting
New Folder R-51 on line frequency induction melting furnaces in modern zinc and aluminum die casting plant. *Ajax Engineering Corp.*

541. Inspection
16-page catalog on illuminated Borescopes for industrial inspection of deep recessed areas. *National Electric Instrument Div.*

542. Investment Casting
8-page bulletin on wax injection presses for investment casting. *Alexander Saunders*

543. Laboratory Equipment
New bulletin on cutting test specimens describes methods for different types of metals. Price list. *Sieburg Industries*

544. Laboratory Furnace
Data on nonmetallic resistor furnaces for research, testing or small-scale production. *Harrop Electric Furnace*

545. Leaded Steel
8-page bulletin gives chemical composition, mechanical properties and case studies showing machining production rates of Ledloy, lead bearing steel. *Ryerson*

546. Leaded Steels
16-page booklet on basic characteristics, mechanical properties and workability of leaded steels. Case histories. *Copperweld Steel Co.*

547. Low-Temperature Treatment
4-page bulletin on low-temperature treatment and equipment. *Alpha Electric Refrigeration*

548. Lubricant
Bulletin 426 on use of colloidal graphite for forging, wire drawing, piercing, drawing, extrusion and other metalworking operations. *Acheson Colloids*

549. Lubricant
New 8-page Bulletin 304 on use of molybdenum disulfide lubricant in cold forming, cold heading and other applications. Case histories. *Alpha Molykote*

550. Lubricants
8-page booklet on colloidal greases, forging compounds, hydraulic concentrate and others. *Grafo Colloids*

551. Machining Titanium
8-page bulletin on turning, milling, drilling, tapping, grinding. Recommendations for each. Typical properties of titanium. *Mallory-Sharon Metals*

552. Magnetic Alloys
Article on use of vanadium in magnetic alloys. Comparison of Supermendur and Permendur. Vancoram Review, Fall 1957. *Vanadium Corp.*

553. Melting Furnaces
28-page catalog and new folder on Heroult electric furnaces. Design, types, sizes, capacities, ratings. *American Bridge*

554. Metal Analysis
New brochure on production X-ray Quantometer. Principle, design, applications. *Applied Research Labs.*

555. Metal Cleaning
Data sheet on Alkontrol, addition agent for metal cleaning and cyanide copper baths. *Northwest Chemical Co.*

556. Metal Forming
Folder on rolling mills, swaging machines, wire shaping mills, wire and tube drawing machines. *Fenn Mfg.*

557. Metal Marking
New bulletin on all purpose electric pen which will arc etch any metal. *Newage Industries*

(Continued on page 43-A)

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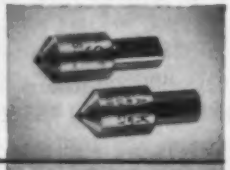
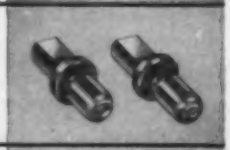
for All Your "Rockwell Testing" Needs

CLARK Diamond Cone Penetrators are exactly right for your "Rockwell" hardness tester, whether or not it bears the CLARK name. Every step in their manufacture, from careful diamond selection to expert lapping, leads to a precision product that will give you precision results. Yet CLARK Diamond Penetrators cost surprisingly little.



CLARK Steel Ball Penetrators, for accurate "Rockwell testing" of unhardened steel, cast iron, brass, bronze, and similar materials, are available in all standard sizes.



CLARK Test Blocks, in various hardness grades, provide a quick, sure, and simple method of checking the accuracy of your "Rockwell" type hardness tester.

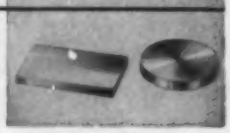


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Photo and data courtesy of The International Nickel Co., Inc.

Why automotive manufacturers prefer N-A-X® FINEGRAIN STEEL for bumpers

WIDE RANGE OF SHAPES AND CONTOURS
The complexity of today's automotive bumpers demands a steel that provides maximum strength plus unlimited shape and contour possibilities.

FLAT POLISHES TO A HIGH LUSTER
The hardness and fine grain of N-A-X FINEGRAIN renders this steel capable of assuming a high degree of luster at minimum cost.

REDUCES POLISHING COSTS
Bumpers made of polished N-A-X FINEGRAIN suffer no surface disturbances due to coarse grain or strain caused by the drawing process. Preparation costs before plating are thereby reduced.

LESS OVERHANG WEIGHT
Generally, the most difficult bumpers can be made of N-A-X FINEGRAIN with a minimum of 25% increased yield strength over mild carbon steel. This makes possible greater resistance to indentation and substantially decreased overhang weight.

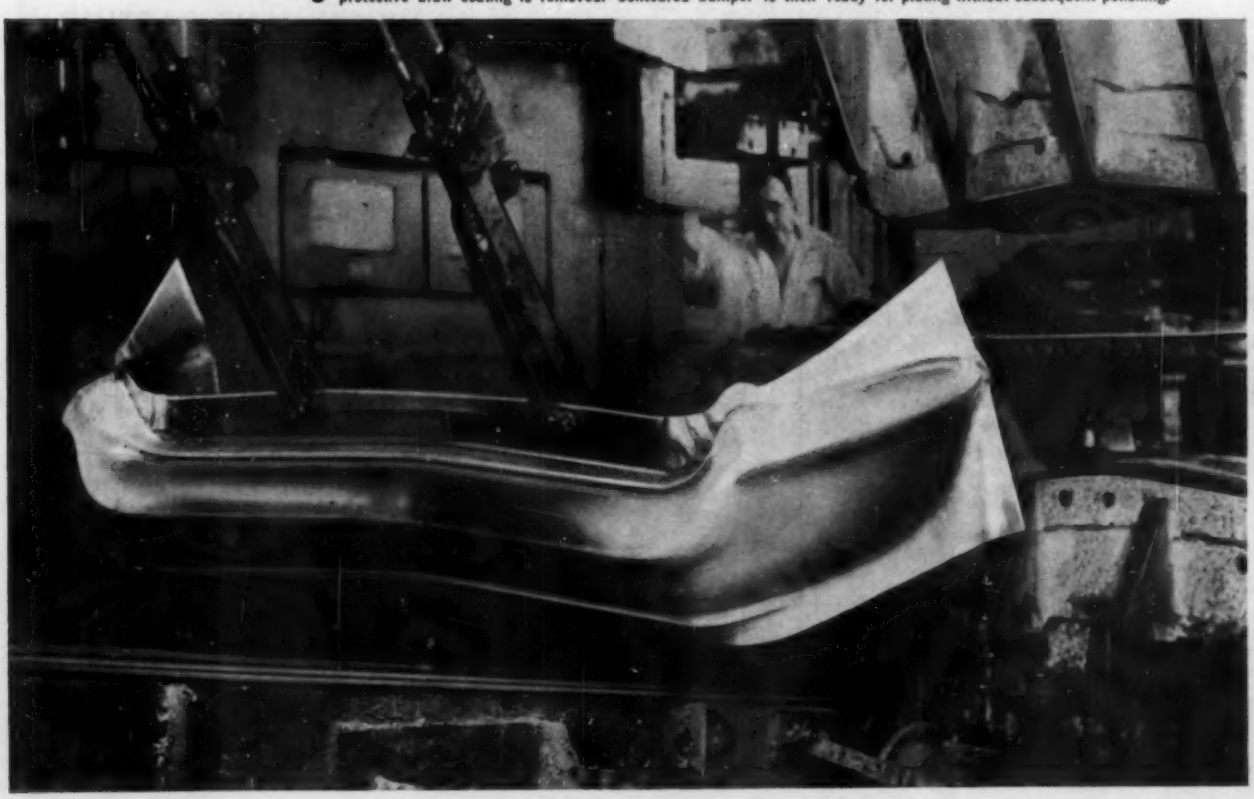
No wonder automotive manufacturers prefer dependable N-A-X FINEGRAIN for the difficult jobs.

CHECK THESE IMPORTANT ADVANTAGES FOR YOUR JOB:
N-A-X HIGH-STRENGTH steels—both N-A-X HIGH-TENSILE and N-A-X FINEGRAIN—compared with carbon steel, up to 50% stronger • have high fatigue life with great toughness • are cold formed readily into difficult stampings • are stable against aging • have greater resistance to abrasion • are readily welded by any process • offer greater paint adhesion • polish to a high luster at minimum cost.

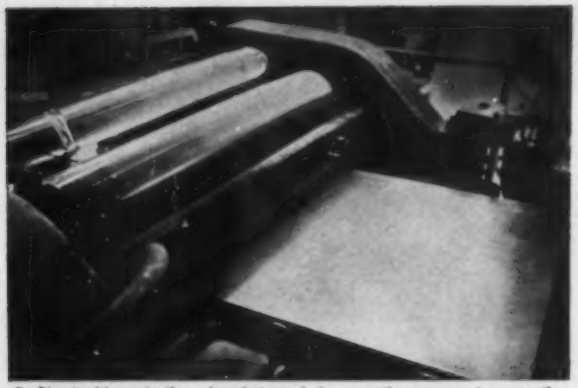
Although N-A-X FINEGRAIN'S resistance to normal atmospheric corrosion is twice that of carbon steel, N-A-X HIGH-TENSILE is recommended where resistance to extreme atmospheric corrosion is important.

For whatever you make, from steel boats to steel bumpers, with N-A-X HIGH-STRENGTH steels you can design longer life, and/or less weight and economy into your products. Let us show you how.

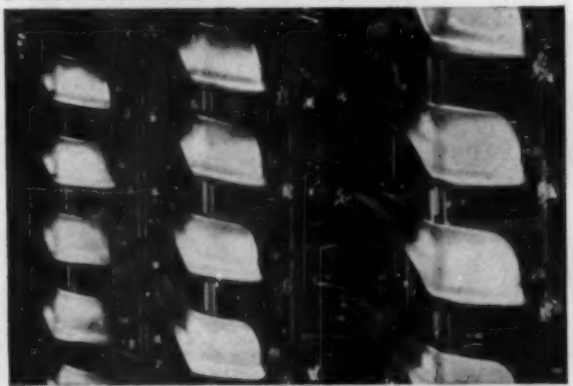
3 Bumper wings, drawn double from N-A-X FINEGRAIN, emerge from press. After splitting and trimming, the protective draw coating is removed. Contoured bumper is then ready for plating without subsequent polishing.



1 Hot rolled N-A-X FINEGRAIN sheets come out of flat polish with a finish of less than 10 microinches.

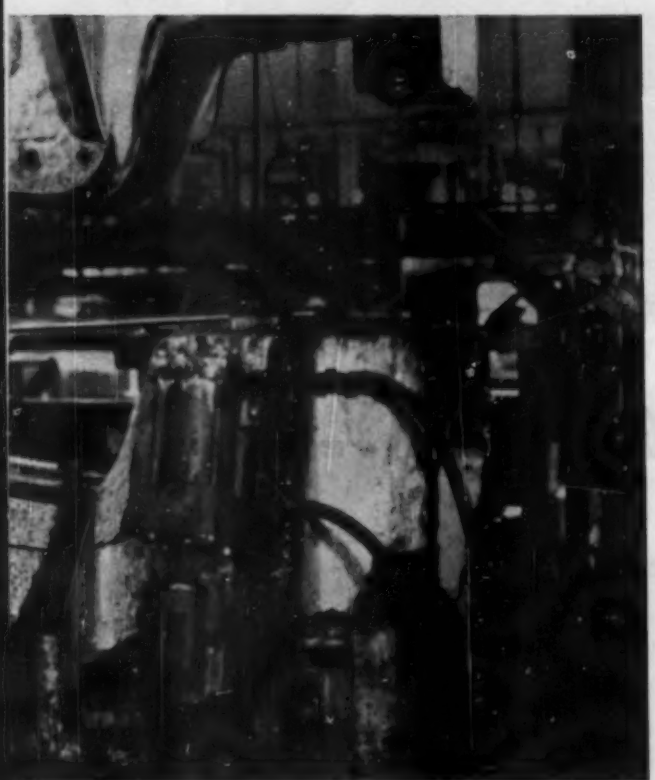


2 Sheet with protective phosphate and draw coatings comes from coating machine ready for the draw press.



4 Bumper wings loaded on elevator for plating. Protective coating has been removed. Note no surface disturbances occurred after drawing operation.

5 Final inspection after plating. No expensive hand-polishing was required from original flat polish to plating operation.



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HIGH-STRENGTH STEELS

Product Development Division, Dept. E-6

GREAT LAKES STEEL CORPORATION

Detroit 29, Michigan • Division of

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Product Development Division, Dept. E-6
Great Lakes Steel Corporation, Detroit 29, Michigan

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Assume that you've just designed a high pressure cylinder to be used in the production of high energy explosives. It is a good sized forging—the main cylinder is 50¼" long, 31½" O.D., and 18" I.D.—with high physicals. It must be forged of a highly alloyed chromium nickel molybdenum vanadium steel to obtain a tensile of 164,000 psi . . . a yield point of 153,000 lbs. . . . and hydrostatic test at 30,000 psi.

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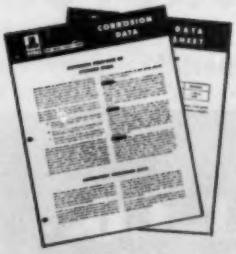

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(Continued from page 43)

558. Metallograph
8-page catalog E-240 on research metallographic equipment discusses microscope unit, illuminator, optical equipment, camera, focusing arrangements. *Bausch & Lomb*

559. Microhardness Tester
Bulletin describes the Kentron microhardness tester. *Torsion Balance*

560. Microscope
New bulletin CM2990 explains how objects can be brought onto optical axis without altering height of stage. How to focus in 1 micron graduations. *Cook Metallurgical Microscopes*

561. Microscopes
40-page catalog on metallographs, metallurgical, toolmakers, stereoscopic, polarizing, phase and other microscopes. *Unitron Instrument Div., United Scientific*

562. Nitrogen Generator
6-page Bulletin No. I-100 gives flow diagram and explains operation. *C. M. Kemp Mfg. Co.*

563. Nondestructive Testing
8-page bulletin on equipment for nondestructive testing of bars, rods, tubing. *Magnetic Analysis*

564. Nonferrous Melting
Bulletin 26-A on high-frequency furnaces for melting copper, silver, gold, platinum, aluminum and magnesium. *Ajax Electrothermic*

565. Nonferrous Wire
Folder gives wire gage and footage chart and data on beryllium copper, phosphor bronze, nickel, silver, brass and aluminum wire. *Little Falls Alloys*

566. Nuclear Forgings
New 6-page brochure on carbon, alloy and stainless steel forgings for nuclear reactor applications. *U.S. Steel Corp.*

567. Oil Quenching
8-page brochure tells in detail how carbon steel often can replace alloy steel when additive is used in the quenching oil. *Aldridge Industrial Oils*

568. Openhearths
12-page booklet shows how openhearths are built. Furnace binding, refractories, combustion and controls, and mechanical equipment. *Loftus Engineering*

569. Ore Beneficiation
New 12-page brochure on new direct reduction and beneficiation process for iron. Ores treated, testing method and licensing procedures. *R-N Corp.*

570. Ovens
New 14-page Bulletin No. 53-CM on various types of core and mold ovens. Construction, operating principle, advantages. *Carl-Mayer*

571. Ovens
New folder, Form 4999 on ovens for baking, drying and product heating. Continuous conveyor-line or complete portable ovens. Application data. *Lighting Div., Safety Industries, Inc.*

572. Ovens
16-page Bulletin 157 on ovens for baking, drying, curing and heat treating. Batch and conveyor types. Air recirculating and heating systems. *Young Bros.*

573. Oxygen Indicator
New Bulletin No. 0817-1 on oxygen indicator. What it is, who can use it, how it works. Accessories. *Mine Safety Appliances*

574. Paint Removers
New booklet on twelve different paint stripping compounds, each designed to remove different type paints. Four methods used and treatment of metals before repainting. *Oakite Products*

575. Perforated Metals
156-page catalog on what materials are perforated, where perforated sections are used and what perforation patterns are available. *Harrington & King Perforating*

576. Phosphate Coating
New bulletin on phosphate coating of iron and steel with Granodine. How applied. *Amchem Products, Inc.*

577. Phosphor Bronze
4-page technical bulletin T-4 on advantages and fabrication of fine-grain phosphor bronze. *Riverside-Alloy Metal*

578. Pickling Baskets
Data on baskets for degreasing, pickling, anodizing and plating. *Jelliff*

579. Plating
8-page brochure on test equipment for plating baths. Controls, anodes, cathodes, agitators, rectifiers. *R. O. Hull*

580. Polishing
6-page article in Metal Digest, V. 4, No. 3, discusses the effects of pressure in mechanical polishing. *Buehler, Ltd.*

581. Powder Metallurgy
12-page bulletin B-101 on furnaces for sintering powder metal products and reduction of metallic oxides. *Drever*

582. Powder Metallurgy
4-page folder presents extensive powder metallurgy bibliography for 1954 and 1955. *Harper Electric*

583. Powdered Iron
New 12-page Bulletin No. 2 on iron powders. Properties of Plast/Iron, Plast/Steel, Plast/Nickel, Plast/Manganese and Plast/Silicon. *Plastic Metals Div.*

584. Precious Metals
Data on bright gold, bright silver, rhodium plating and salts. *Sel-Rex*

585. Precision Casting
8-page bulletin on investment castings of various ferrous and nonferrous alloys. *Engineered Precision Casting*

586. Presses
Data on mechanical and hydraulic powdered metal presses 8 to 500-ton capacities. *Haller, Inc.*

587. Presses
New 12-page Bulletin 50 on extrusion presses and processing machines. Size, design, uses. *Sutton Engineering Co.*

588. Protective Coatings
Folder 301 on industrial protective coatings of rubber, neoprene and other materials. *Arco Steel Fabricators*

589. Pyrometers
Catalog 168 on surface pyrometer for surface and subsurface temperature readings. *Pyrometer Instrument*

590. Quenching
Catalog FR-853 on two small self-contained quenching units. *Bell & Gossett*

591. Radiography
20-page bulletin on gamma radiography. Uses, sources, equipment. *Nuclear Systems Div., Budd Co.*

592. Radiography
16-page booklet on materials and accessories for industrial radiography. Guide to selection of film. Recommended development techniques. *Eastman Kodak, X-Ray Div.*

593. Recirculating Furnace
New Bulletin No. 13-A on continuous-type recirculating furnace shows design of furnace, its operation and advantages. *Industrial Heating Equipment Co.*

594. Refractories
12-page catalog shows properties of impervious recrystallized alumina and impervious mullite. Shapes into which each is fabricated. *Morganite, Inc.*

595. Refractories
New bulletin, 1922, on two high temperature Alundum castable refractories. Properties and how to use them. *Norton*

596. Rolling Mills
Data on 2-high/4-high combination rolling mill for metallurgical production and research. *Loma Machine Mfg. Co.*

597. Rust Prevention
Nine bulletins in one folder on rust

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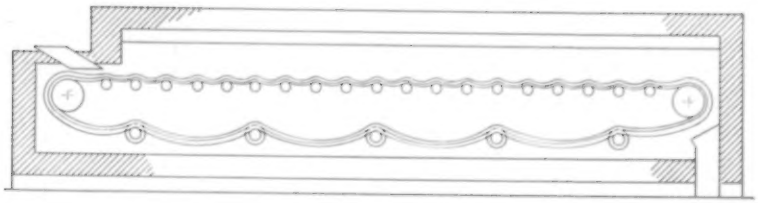

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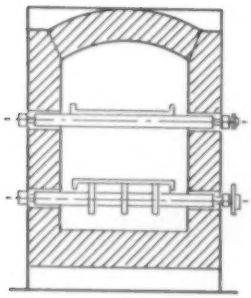

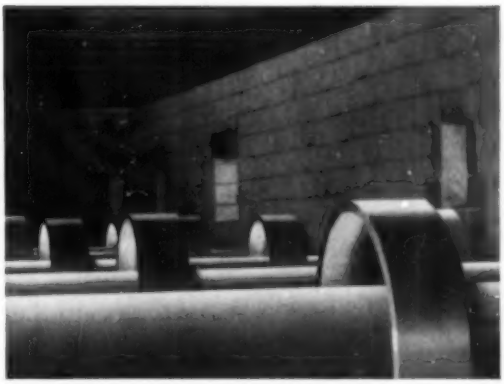

HOLCROFT PATENT DROPS CONVEYOR FURNACE COSTS

Holcroft engineering has done it again! This time to effect a reduction of up to 75% in *original* conveyor furnace belt costs. And years of rigorous testing under actual operating conditions proves that you'll get longer belt life, to boot. The key? Holcroft's exclusive, *patented* (#2,780,454) conveyor belt supporting and driving system . . . a system utilizing driven, synchronized support rollers under both load bearing and return sections of the conveyor belt in conjunction with end drums which function primarily as idlers. No tension is required to move the belt . . . total belt tension is confined to that developed by the load between rollers . . . take-up devices, ordinarily required to tighten belt between end drums, are unnecessary. These advantages permit the use of low-cost, lightweight conveyor belting. And it will last and last even under rugged loading conditions . . . as has already been proved in a Holcroft installation of this type where the belt is still going strong, *without* "crankshafting", after five years! Interested? Write today.

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FOR EVERY PURPOSE

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control your quality...

with STAINLESS and STRIP DIVISION

cold rolled spring steel

The quality of your spring steel parts or products is only as good as the spring steel itself—its response, its performance. When you specify J&L it means all the advantages of most exacting quality control—from ore to finished coil. Particularly important is the opportunity to utilize J&L's Restricted Specification processing to achieve the qualities necessary for optimum end-results. With individual restricted specifications met, often-times production operations can be simplified and in many instances product quality improved. As an example look at this . . .

TYPICAL APPLICATION . . .

results	specification	product
Hardened Control Bar	Spring Steel. Analysis—AISI—1050 annealed. Size 4½" x .042. Tolerance ± .0003 including crown. Width tolerance ± .005. Temper—B78 Max. Finish—#2. Coil size 250/300 lbs. per inch width.	Uniformity of shape and gauge made possible change from cut lengths to coils, reducing handling and inspection. Increased speed of production line. Amazing thickness control eliminated 2 quality control stations.

The experience, facilities and accumulated know-how of a specialized organization devoted exclusively to strip steel processing are available to work with you. In this clearing house of strip steel engineering and application information, it's a good bet there is something of value for you. Your inquiry will get our immediate, interested attention.

J&L STAINLESS and STRIP DIVISION produces a full line of restricted and standard specification strip steel in these grades and types:

Low Carbon	Electrolytic Zinc, Tin, Copper & Brass Coated
High Carbon	Alloy
Tempered Spring Steel	Stainless
Molten Zinc Coated (Jal Zinc)	Painted

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Jones & Laughlin
STEEL CORPORATION
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prevention. Theory of corrosion. Applications. *Production Specialties*

598. Rust Prevention

Bulletin No. 51 on anionic surface active agent for oil-soluble rust and corrosion inhibitors, emulsifying, wetting and dispersing agents. *Sun Oil*

599. Salt Bath Furnaces

Data on salt bath furnaces for batch and conveyorized work. *Upton*

600. Saws

Catalog C-55 describes 35 models of metal-cutting saws. *Armstrong-Blum*

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Bulletin on bar and billet shear for rounds, squares, flats, billets and structurals, either hot or cold. *Hill Acme Co.*

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76-page handbook on multiple rotary slitting lines. Design, selection and operation of slitters. Specifications and capacity tables. *Yoder Co.*

603. Soldering Flux

New bulletin on aluminum soldering flux used to join aluminum to aluminum or aluminum to other metals. Operating temperatures from 600 to 675° F. *American Solder & Flux Co.*

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New 8-page catalog on Spec-Lab. Performance and applications of three models. *Jarrell-Ash*

605. Spray Painting

New 6-page booklet on airless spraying. How it works, advantages. *Nordson*

606. Spring Steels

48-page booklet on selection of spring steel. How it is made, hardness values, physical property data. *Wallace Barnes*

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6-page folder gives applications, materials, finish and size range. Analyses. *Sandvik Steel*

608. Stainless Castings

28-page booklet of data on stainless castings. Analyses, properties, handling and heat treatment. Typical applications. *Allegheny Ludlum Steel*

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New 20-page manual on stainless steel wire. Analyses, mechanical properties, corrosion data, applications. *Jones & Laughlin*

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New 16-page catalog describes sulphur and carbon determinators. Accessory equipment and supplies. *Harry W. Dietert*

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New Bulletin 24-1 on selector switches for temperature measuring circuits. Types, construction and capacities. *Thermo Electric*

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613. Testing Machines

New 28-page catalog on fatigue testing machines. Specifications, working principles. *Riehle*

614. Testing Machines

Bulletin on Brinell hardness, ductility, compression, tensile, universal, transverse, hydrostatic proving instruments. *Steel City Testing Machines*

615. Thermocouple Assemblies

Bulletin No. TA-457 gives sizes, prices, ordering information. *Claud S. Gordon*

616. Thickness Gage

Folder on pocket-size gage. How to use it. *Ferro Corp.*

617. Thickness Tester

Data sheets give ranges, principle of operation of nondestructive thickness tester. *Unit Process Assemblies*

618. Tin

20-page bulletin on importance of tin to the American industry. Applications in aircraft, chemical, container, electrical, electronic equipment and others. *Malayan Tin Bureau*

619. Titanium

New bulletin on titanium production and use. Mechanical properties. *Republic Steel Corp.*

620. Titanium Powders

Data on high purity and commercial titanium powders. *Hawkridge Metals.*

621. Tool Steel

New 10-page Booklet 458 on general purpose tool steel. Analysis, uses, characteristics, wear resistance. *Bethlehem Steel*

622. Tool Steel

Color guide to estimate temperatures has heat colors on one side and temper colors on the other. *Bethlehem Steel*

623. Tubing

New 10-page Bulletin No. 70 on superalloy tubing. Chemical composition, physical and mechanical properties. 8 tables, 8 graphs. *Superior Tube*

624. Tungsten

20-page bulletin on manufacture, properties and uses of tungsten. Flow chart of tungsten production. *Sylvania Electric Products*

625. Tungsten Alloy

Bulletin on properties and uses of 90% tungsten alloy, balance nickel and copper. *Firth Sterling, Inc.*

626. Ultrasonic Cleaning

New 24-page Bulletin S-200 explains practical applications and basic principles of ultrasonic cleaning. *Branson*

627. Ultrasonic Cleaning

12-page article on new ultrasonic cleaner for use with metallographic specimens. Metal Digest, V. 3, No. 1. *Buehler, Ltd.*

628. Ultrasonic Inspection

Ultrasonic Inspection Newsletter, No. 2, contains article on immersion inspection of wing spars for jet fighters. *Sperry*

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New bulletin on vacuum melting furnaces which can be used in production or laboratory. *Zak Machine Works*

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New 68-page Bulletin 6-1 on high vacuum vapor pumps. Describes technique and pumping systems. Tables, charts and graphs. *Rochester Div., CEC*

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New 24-page Catalog V-58 on magnetic and motorized valves for use with air, water, gas, steam, oil and refrigerants. Dimensional drawings included. *Mercoid*

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Series of reference data charts on welding electrodes and filler rod. Melting rates, efficiences and recommended welding currents. *Ampco Metal*

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Catalog on Cadweld process and arc-welding accessories. *Erico Products*

635. Welding Steel Castings

52-page book on recommended practice for repair and fabrication welding of steel castings. 18 pages of tables. *Tempil®*

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130-page reference manual on mesh specifications, design, metallurgical data. *Cambridge Wire Cloth*

637. X-Ray Film

Technical data on line of Structurix films. *Gevaert Co.*

638. Zinc Coating

New 8-page booklet on zinc-coated steel sheets. Fabrication, uses, advantages in heating, ventilating and air conditioning. *Weirton Steel*

September, 1958

425	445	465	485	505	525	545	565	585	605	625
426	446	466	486	506	526	546	566	586	606	626
427	447	467	487	507	527	547	567	587	607	627
428	448	468	488	508	528	548	568	588	608	628
429	449	469	489	509	529	549	569	589	609	629
430	450	470	490	510	530	550	570	590	610	630
431	451	471	491	511	531	551	571	591	611	631
432	452	472	492	512	532	552	572	592	612	632
433	453	473	493	513	533	553	573	593	613	633
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436	456	476	496	516	536	556	576	596	616	636
437	457	477	497	517	537	557	577	597	617	637
438	458	478	498	518	538	558	578	598	618	638
439	459	479	499	519	539	559	579	599	619	
440	460	480	500	520	540	560	580	600	620	
441	461	481	501	521	541	561	581	601	621	
442	462	482	502	522	542	562	582	602	622	
443	463	483	503	523	543	563	583	603	623	
444	464	484	504	524	544	564	584	604	624	

METAL PROGRESS,

7301 Euclid Avenue, Cleveland 3, Ohio

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Name _____

Title _____

Company _____

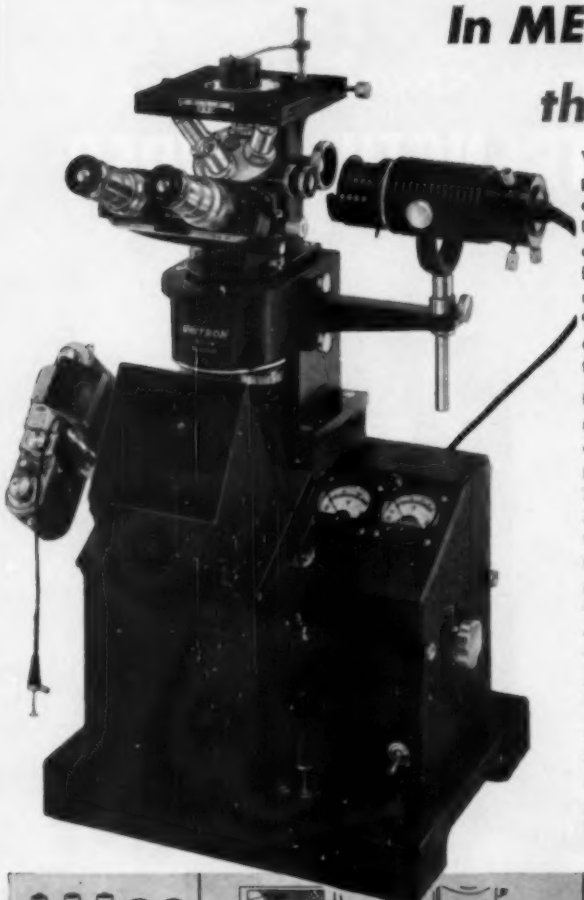
Address _____

City and State _____

Postcard must be mailed prior to Dec. 1, 1958. Students should write direct to manufacturers.

In METALLOGRAPHS...

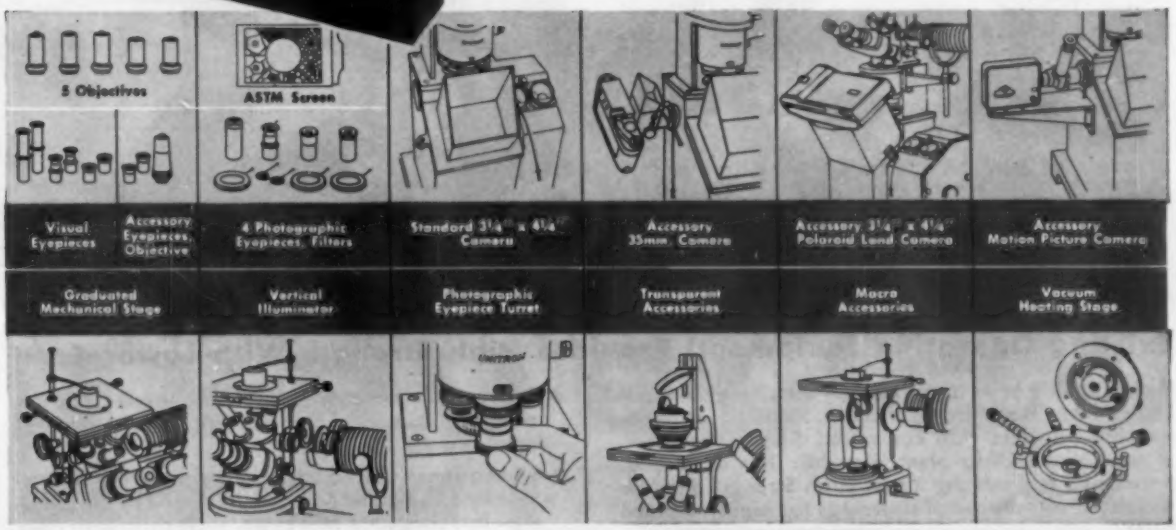
the trend is to UNITRON!



What do you look for when choosing a metallograph? All of the popular makes are precision instruments, are reasonably versatile and, to a varying degree, are easy to operate. But, except for UNITRON, all have the bulk of an office desk or optical bench and are tagged with a price that puts a substantial dent in the laboratory budget. UNITRON, and only UNITRON, offers a completely equipped metallograph in a compact and self-contained unit, taking only 9" x 12" of table space, which duplicates the performance of large cumbersome instruments — and at a price which is hardly more than the usual cost of a conventional metallurgical microscope.

Unlike the case with most metallographs, an adding machine is not required to compute its cost. Coated optics supplied as standard equipment include 5 objectives, 4 photographic eyepieces and 3 pairs of visual eyepieces. These give a magnification range of 25X-2000X. Also included in the purchase price are the built-in 3¼" x 4¼" camera and viewing screen; high-intensity illuminator for vertical, oblique, and transmitted light; variable transformer with both voltmeter and ammeter; accessories for transparent specimens; polarizing apparatus; filters; film holders; stage clips; cabinets etc. Optional extra accessories include Polaroid Land, 35mm. and movie camera attachments; low power (5X-40X) objectives for macro work; vacuum heating stage for temperatures to 1100°C and long working-distance 40X objective; ASTM Austenite grain size viewing screen and eyepieces; filar micrometer eyepiece; and additional optics.

Such a combination of features, versatility, convenience, and value is indeed unique with UNITRON. Little wonder then, that more and more laboratories are choosing UNITRON . . . from the large organization adding another metallograph to its equipment, to the small company buying an instrument for the first time.



FREE 10 DAY TRIAL

UNITRON's Metallograph and Universal Camera Microscope Model MU-11 with binocular eyepiece; objectives: M5X, M10X, M40X, 40X for transmitted light, 100X oil immersion; paired visual eyepieces: R5X, Ke10X Micrometer, Ke15X; photo eyepieces: 10X, 15X, 20X, Micrometer; etc., as described above.

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THE TREND IS TO UNITRON

Republic Steel Announces Result of Project 501...

A NEW HIGH STRENGTH POWDER

Type 6460 Developed for Use in Higher Stressed Applications! Suited to Existing Operating Equipment! Provides High Strength With Lower Cost!

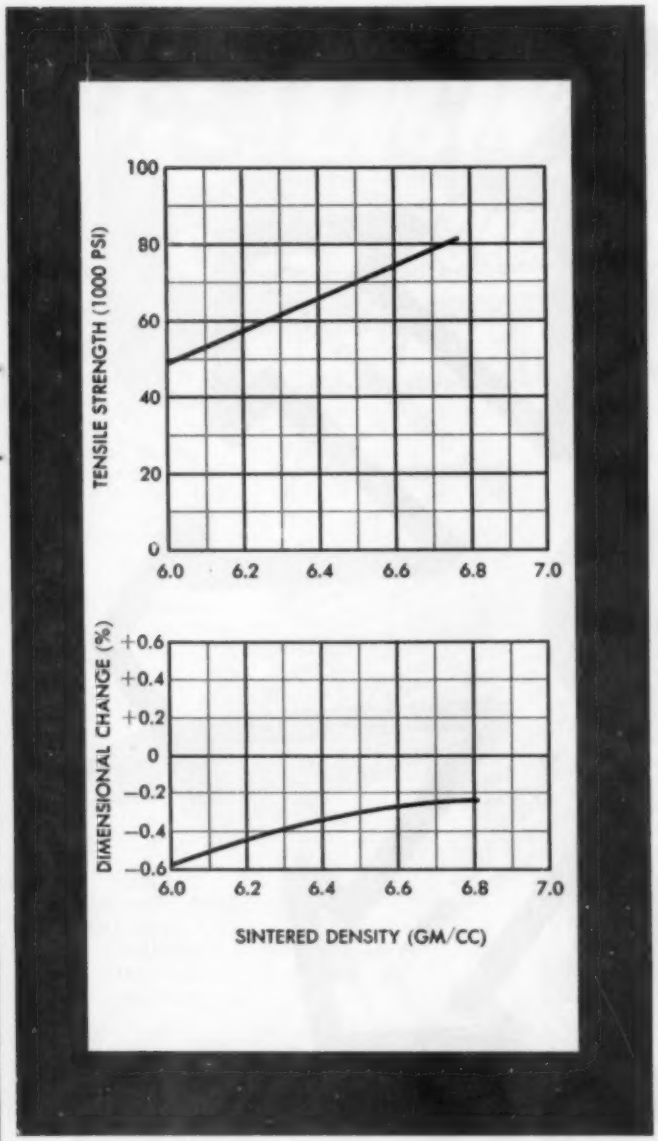
Again, the big news in the powder metallurgy industry comes from Republic Steel. First, Republic gave the industry powders with controlled dimensions. Now, at its Toledo, Ohio plant, Republic has developed, tested, and is *producing* a new **H**igh **S**trength Powder which permits the use of sinterings for highly stressed parts.

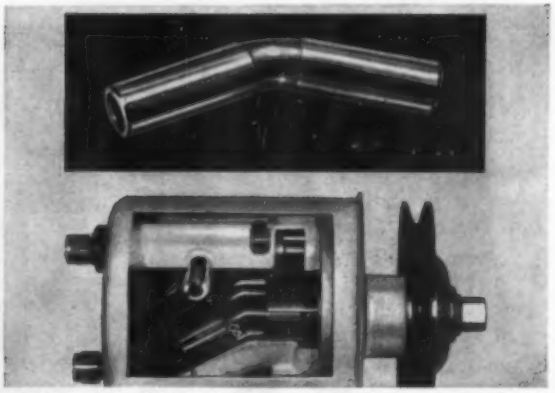
This new powder, designated Republic Type 6460, provides these advantages and features:

- Minimum tensile strengths at 6.4 density of 60,000 p.s.i. as sintered, and 100,000 p.s.i. heat treated, as determined on standard MPA Test Bar.
- *Can be used with existing operating equipment.*
- Normal briquetting pressures—30 to 35 tons to obtain a density of 6.4 grams/cc.
- Normal sintering cycles—2030°F. to 2050°F.—45 minutes—Endo Atmosphere.
- Normal heat treat procedures—additional information to obtain higher physical properties available upon request.
- Dimensional characteristics after sintering acceptable by commercial practices indicated by the industry—less than .004 inches per inch shrinkage from die size at 6.4 density.
- Available in *production quantities* up to and including 12 tons, or in multiples thereof.

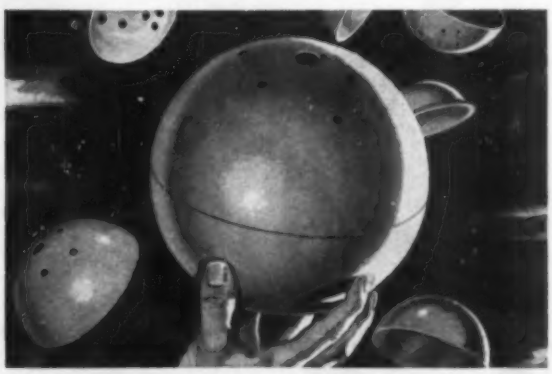
Republic Type 6460 Powder represents an entirely new, but thoroughly practical material for the powder metallurgy industry. It opens the way to new markets for new applications of **H**igher **S**tressed parts at lower costs.

Our metallurgists and engineers are ready to help you utilize all the advantages of Republic Type 6460 Powder. Just mail the coupon to obtain their services, or for technical data sheet on Type 6460 Powder.





WHEN IT'S MOVING... MAKE IT TUBING. Republic ELECTRUNITE Mechanical Tubing meets all close tolerance requirements for new Thompson Products automotive hydraulic pump assembly. Close tolerance, uniformity, ductility, workability—four important performance requirements, all important reasons why ELECTRUNITE is used. Will-O-Hill Industries, Inc. Willoughby, Ohio, sub-contractor, cut 7/16-inch diameter ELECTRUNITE into units 2 3/16 inches long. Each unit is rolled to form a slight groove in the center and bent to an angle of exactly 150°. Nine such pieces are used in each pump assembly. Send coupon for more information.



STRENGTH, LIGHTWEIGHT, CORROSION-RESISTANCE are advantages of Republic Titanium used in the manufacture of these hemispheres by Alloy Products Corporation, Waukesha, Wisconsin. Used for special aeronautical applications, completed spheres provide light weight without impairing safety; strength to contain 2,000 psi.; extremely high corrosion-resistance to chemically active contents. Beyond providing product advantages, Republic Titanium is easy to draw, pierce, and weld. Little change in fabricating procedure is required as compared with other construction materials. Send coupon for data.

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World's Widest Range of Standard Steels and Steel Products

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☐ Have a powder metallurgist call.
Send more information on: ☐ Type 6460 Powder
☐ ELECTRUNITE® Tubing ☐ Titanium

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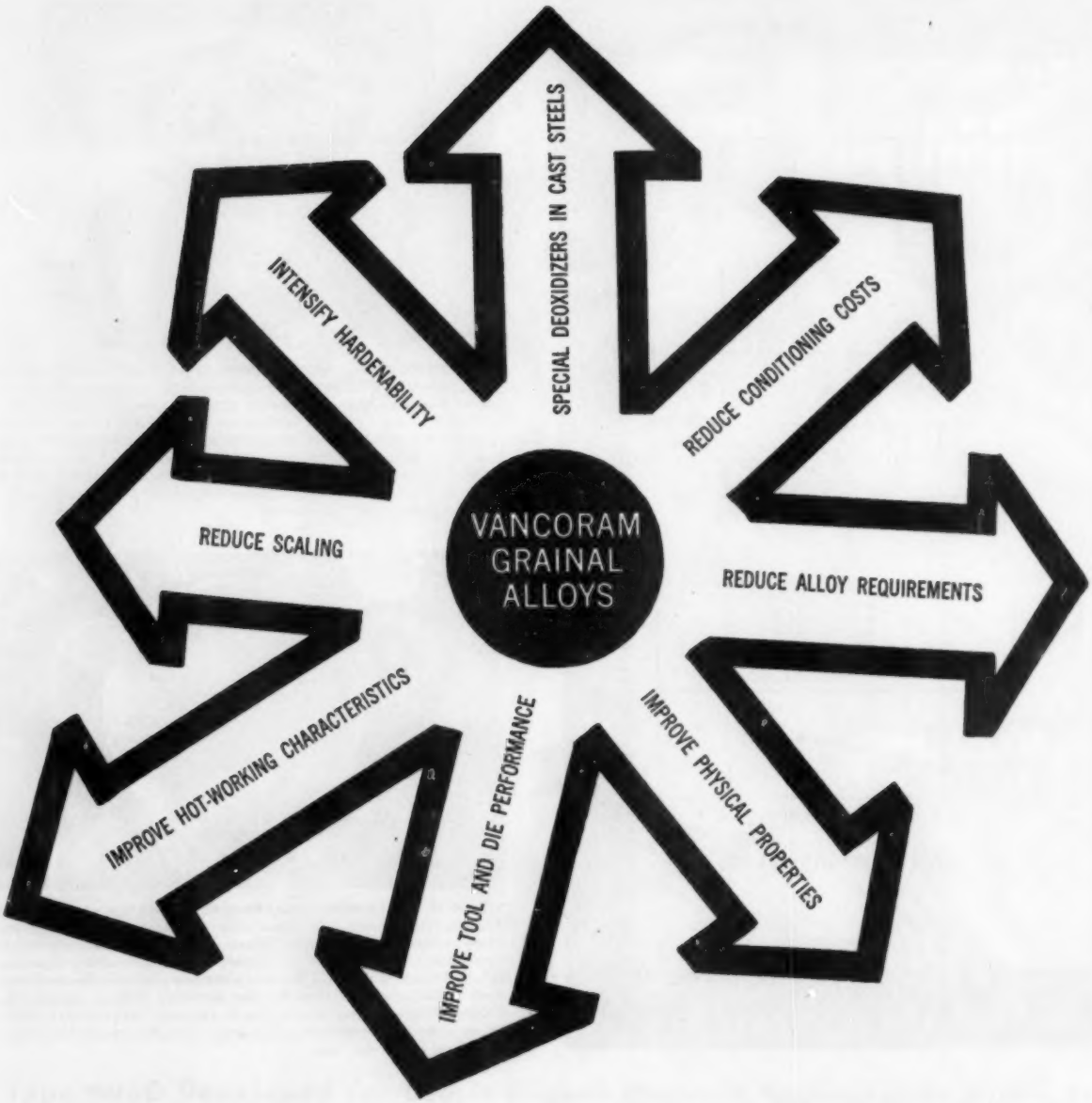

. . . SO MANY JOBS SO WELL! Vancoram Grainal Alloys improve hot-working characteristics and reduce conditioning costs and rejections in stainless and heat-resisting steels. They intensify hardenability, reduce scaling. They improve tool and die performance in cold upsetting, blanking, punching, pressing, forming. Grainal Alloys lower steel cost by reducing alloy requirements, and improve physical properties of high-strength cast steels. And they are used as special deoxidizers in cast steels. What other alloy can do so many jobs so well?

Learn more about the special versatility of Vancoram Grainal from the booklet, "Grainal and Its Use." Write or phone your nearest VCA District Office for your free copy.

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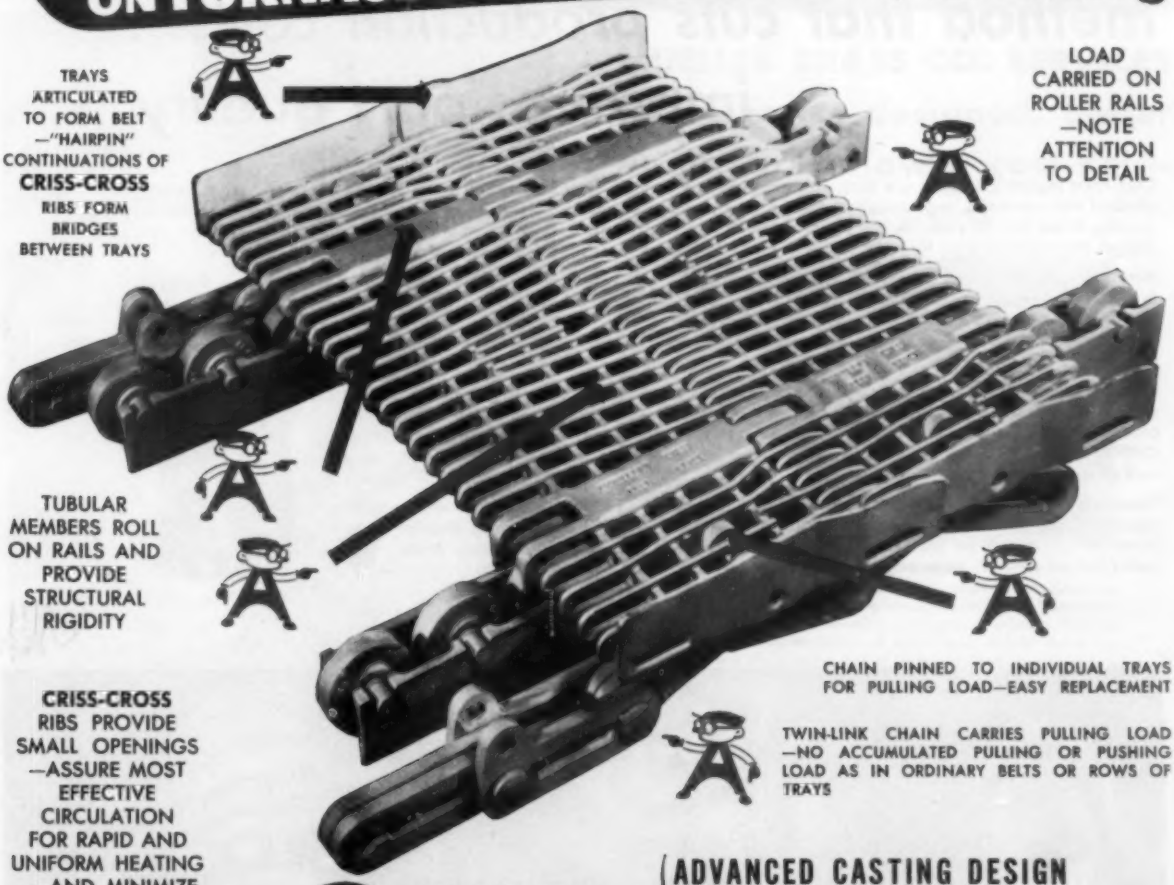
AEC ENGINEERING GIVES Better Service ON FURNACE MECHANISMS

Something NEW has been ADDED!



TRAYS ARTICULATED TO FORM BELT —"HAIRPIN" CONTINUATIONS OF **CRISS-CROSS** RIBS FORM BRIDGES BETWEEN TRAYS

LOAD CARRIED ON ROLLER RAILS —NOTE ATTENTION TO DETAIL

TUBULAR MEMBERS ROLL ON RAILS AND PROVIDE STRUCTURAL RIGIDITY

CHAIN PINNED TO INDIVIDUAL TRAYS FOR PULLING LOAD—EASY REPLACEMENT

TWIN-LINK CHAIN CARRIES PULLING LOAD —NO ACCUMULATED PULLING OR PUSHING LOAD AS IN ORDINARY BELTS OR ROWS OF TRAYS

CRISS-CROSS RIBS PROVIDE SMALL OPENINGS —ASSURE MOST EFFECTIVE CIRCULATION FOR RAPID AND UNIFORM HEATING —AND MINIMIZE AREAS AT INTERSECTIONS FOR IMPROVED METALLURGICAL STRUCTURE

KNOW-HOW IN ADVANCED CASTING DESIGN · FURNACE MECHANISMS · PROPRIETARY CASTING PROCESSES

Creates a NEW Concept in Furnace "Trays"

The customer of a leading furnace manufacturer needed a better alloy product to do a better job. AECCo. INTEGRATED design and casting processes made it possible to produce the job illustrated. Another example of an AECCo. contribution to improved heat treating. Note the ACCOLOY POINTERS for highlights.

HEAT RESISTANT CASTINGS — ACCOLOY — STAINLESS STEEL CASTINGS

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NOW..from MUELLER cold·prest® IMPACT

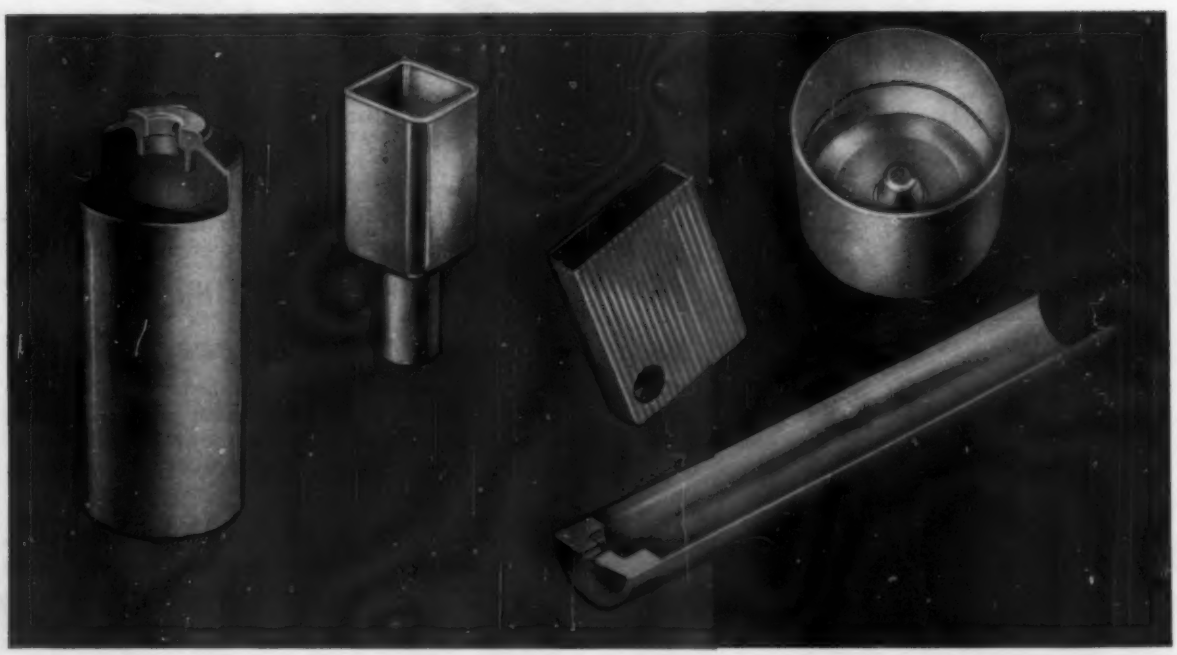
the amazing, new, chipless metalworking method that cuts production costs... ....improves part quality

Cold-Prest Impact Extrusions are here. This amazing new method of producing parts to closer tolerances . . . with better physical characteristics, and with absolutely no waste and at extemely high speed is the greatest development in metal-working in the last 20 years. And it's proving to be the most practical method of manufacturing a staggering number of designs that combine cold forged bases with shells shaped as rounds, ovals or rectangles.

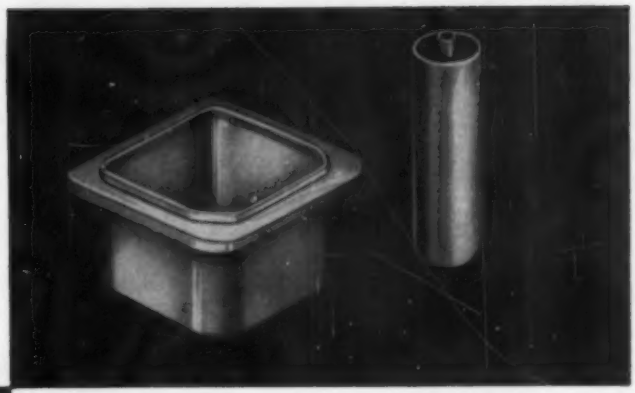
Here are some of the reasons why your company can save money and improve product quality . . . by specifying Mueller Brass Co. Cold-Prest Impact Extrusions. Parts are formed with *no chip loss;* you pay only for the metal that goes into the part. Because of the dimensional accuracy of Cold-Prest extrusions, parts can be held to closer tolerances and many costly secondary machining operations are eliminated. They have better physical properties with actually less metal needed to achieve greater strength.

Cold-Prest Impact extruded parts often *reduce or eliminate assembly operations* because products employing several parts can often be made as a single extrusion. Also, complex parts produced by conventional methods requiring costly machining to close tolerances can be made in *A SINGLE OPERATION* as a Cold-Prest extrusion, saving raw material, costs of time, tools and labor . . . as well as assuring a positive leak-proof part.

These are the outstanding reasons why you should consider Cold-Prest Extrusions when you are specifying and purchasing fabricated metal parts. Call a Sales Engineer from the Mueller Brass Co. . . . he will be glad to discuss your problems and answer your questions. Write today for our new 16 page engineering manual on "Cold-Prest Impact Extrusions".



BRASS CO.
EXTRUSIONS



MUELLER BRASS CO. SERVICES mean better designed, better engineered, lower cost cold-prest extruded parts

To produce precision, high quality impact extrusions, Mueller Brass Co. combines all the important factors of design, engineering and production in its Cold-Prest extrusion process. Trained engineers take into consideration such elements as functional strength, finished appearance and proper control of metal flow. Mueller Brass Co. offers this design engineering service to its customers, and engineers are always available for consultation.

Here a die and punch assembly, made to exacting tolerances and with a mirror-like finish, receives a final inspection in the tool and die shop before being sent to the production department. Skilled craftsmen work with the best equipment available to produce these precision tools and dies. Technical skill, modern equipment and complete engineering services are available at no extra cost to you.

MUELLER BRASS CO.

MADE IN U.S.A. TO THE STANDARDS OF AMERICAN INDUSTRY

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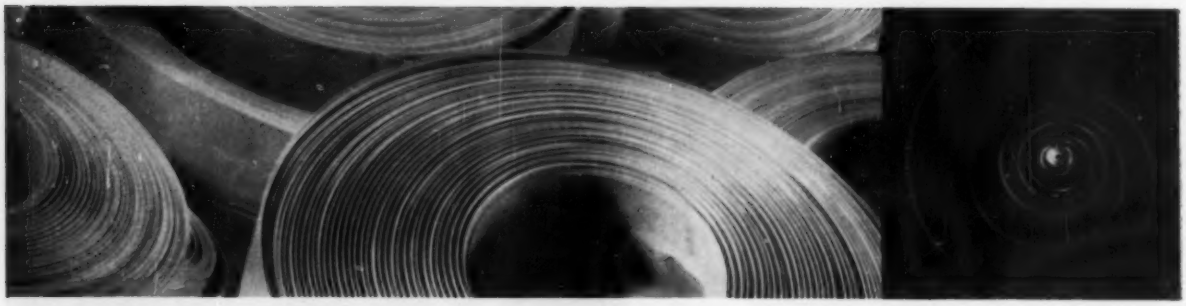
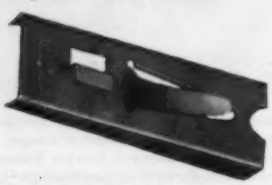


How they're using

Wallace Barnes Cold-rolled Specialty Steels

1. *In Three Drawing Stations*

The part shown in illustration one was made from .59 – .74% carbon steel in three drawing stations. From .70 – .80% carbon, this piece should have four or five drawing stations. The piece could be made from .90 – 1.05% carbon, but would require seven drawing stations with fully annealed steel.



2. *Blanked on 45° Angle*

The stamping shown in the second illustration was made from .70 – .80% carbon spring steel. It was blanked and pierced on a 45° angle, with small holes pierced to prevent fracture in later forming and bending. It was then given severe secondary forming. The small tab shows "orange peel" and probable fracture would occur if the part were formed from .90 – 1.05% carbon.

3. *All Flanging One Operation*

Our third part is a gun stamping made from .70 – .80% carbon with a sharp bend with the grain in one stroke of the press. Higher carbon will fracture due to its less ductile qualities.

4. *Thirteen Steps Progressive*

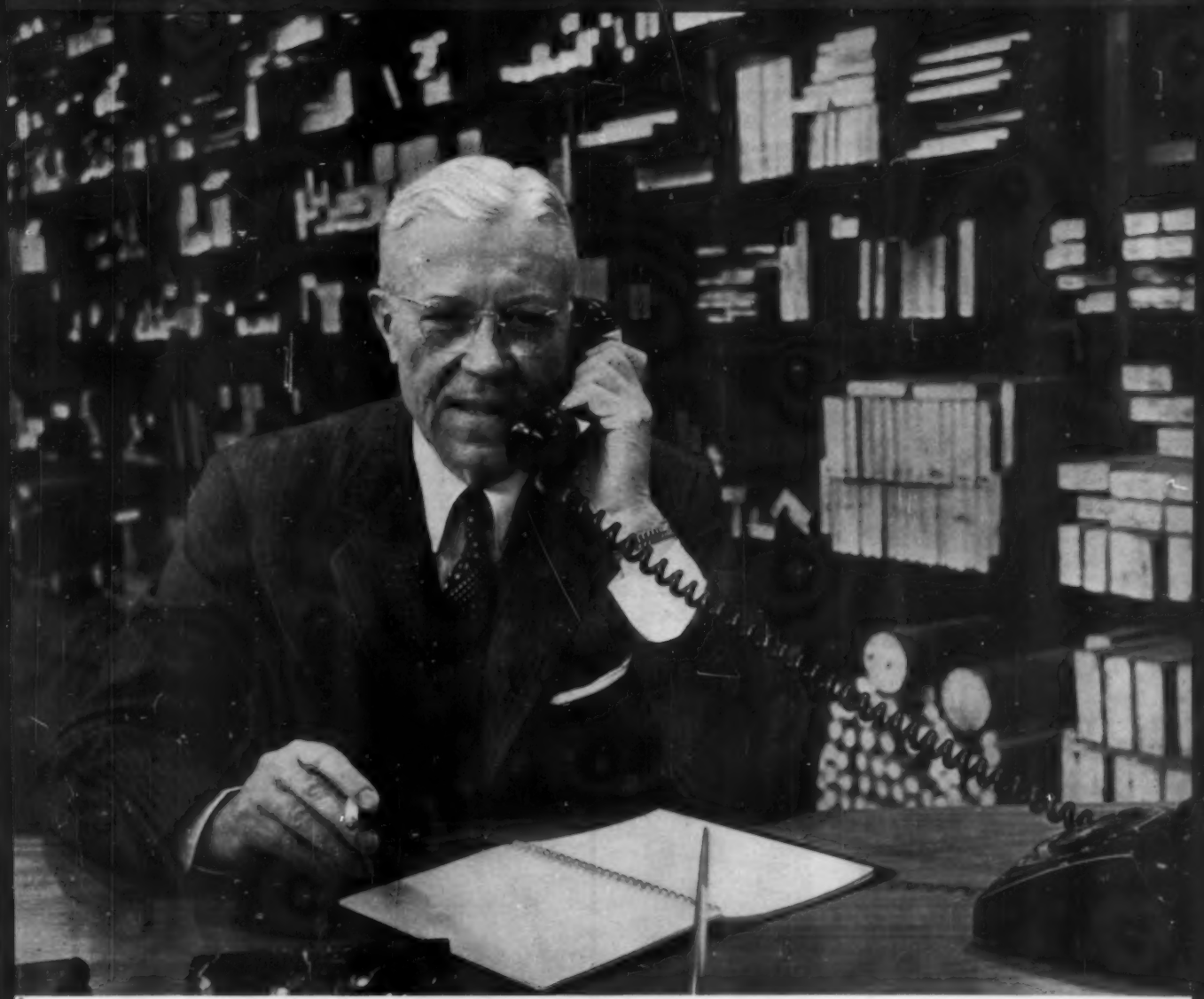
The fastener shown in the fourth illustration was made from the .59 – .74% carbon steel, the only spring steel which would take the bends and draws to which it is subjected here. All the higher carbon steels were rejected because they failed under the cold-work necessary to produce the two small extrusions. It took seven reductions to bring these extrusions within tolerance. There were thirteen steps total in the progressive die.

These examples show how proper steel selection may save operations and insure satisfactory performance. Among the many sizes and types of Wallace Barnes cold-rolled specialty steels is the right one for your application. Send for "Physical Property Charts" giving tensile strength and forming properties of Wallace Barnes tempered steels.

Wallace Barnes Steel Division

Bristol, Connecticut

Associated Spring Corporation



For Answers to Tool Steel Problems

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Virtually every business day you are faced with a question or two about tool steel. On occasion the solution is relatively easy, such as ironing out some detail about delivery. But often it can be considerably more complex—perhaps weighing the merits of two similar grades, or determining the proper cycle of heat-treatment to obtain a more effective die life.

Whatever the problem, it calls for expert opinion, and that's where your Bethlehem tool steel distributor comes in. For he's a specialist in tool steel matters, and it's part of his job to see that your questions are answered promptly and courteously. Besides, he can also save you time when you need tool steel, for his diversified stocks are ready to go at a moment's notice. Make it a point to check with your Bethlehem distributor often. It will take but a few minutes at most, and it's one of the wisest moves you can make.

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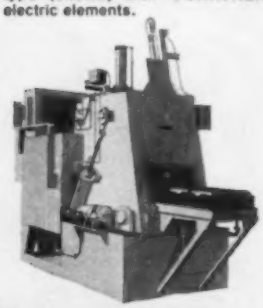
Wherever industry needs heat...

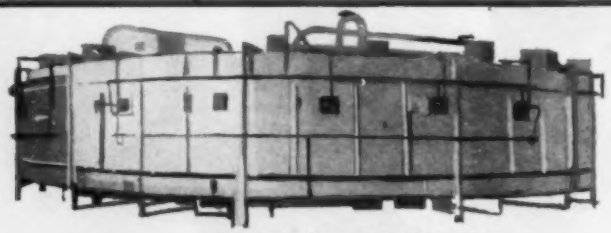
You'll find *LINDBERG* equipment just right for the specific job

Pilot Plant Equipment: Atmosphere tube unit (shown) for processing work at temperatures to 2200° F.

Roller Hearth Furnaces: Continuous electric type (shown) with temperature range 1300° to 2100° F.

Automatic Carbonitriding Furnaces: Automated integral quench type (shown) with CORRTHERM electric elements.



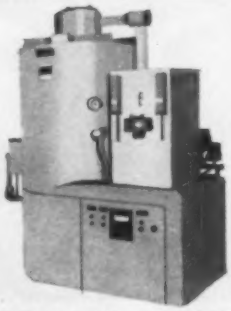


Rotary Hearth Furnaces: Doughnut type field-installed gas-fired furnace (shown) with capacity of 13,000 lbs. per hour.

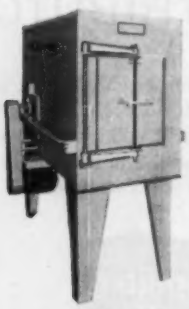
Vertical Type Furnaces: Carburizing and hardening furnace (shown) with CORRTHERM electrical heating elements.

HF Induction Heating Units: Available in 5, 10, 25 and 50 KW units.

Ceramic Kilns: Gas-fired periodic kiln (shown) with temperature range to 3250° F.

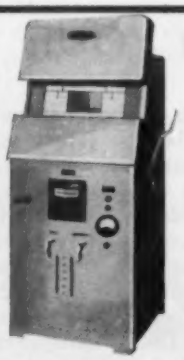


Atmosphere Generators: Hyen generator (shown) for endothermic atmospheres. Generators for all required atmospheres.

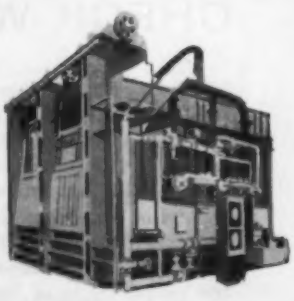


Tempering Furnaces: Box type Cyclone (shown). Temperature range to 1250° F.

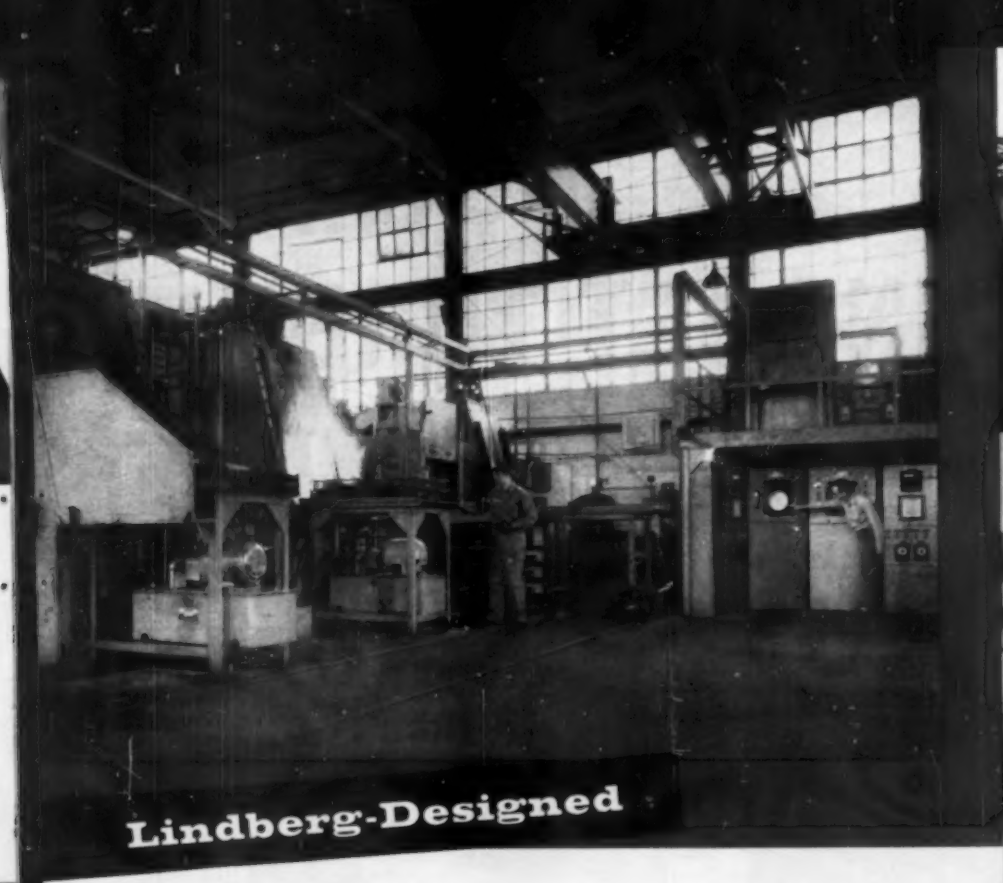
Melting and Holding Furnaces: Electric resistance furnace (shown) with capacities of 750 lbs. to 1500 lbs.



Laboratory Equipment: One-unit box furnace (shown), muffle or for non-oxidizing atmosphere with temperature range to 3000° F.



Aluminum Reverberatory Furnaces: Twin-chamber melting and holding furnace (shown) with 45,000 lbs. capacity.



Lindberg-Designed

Charles Hewitt, President of Dayton, says, "The Lindberg installation has kept our production at a consistently high quality level."

Work loads are positioned manually, but entire furnace operation is fully automatic.

Lindberg Carbotrol unit automatically controls and records "dew point" and heating cycles of endothermic atmosphere.

Lindberg's "dimple" vertical radiant tubes give remarkably trouble-free service and function at all times at full efficiency.

Unique Installation Cuts Heat Treating Costs and Improves Quality at Dayton

Here is a remarkable set-up for general heat treating now in operation at Dayton Forging & Heat Treating Company, Dayton, Ohio. Two integral quench atmosphere furnaces, largest of this type ever built by Lindberg, and one atmosphere tempering furnace in a "three-in-a-row" arrangement that simplifies transfer operation. Combined with Lindberg Carbotrol and Hyen generator, the entire furnace operation is completely automatic, including atmosphere control and recording. Planned by Dayton and Lindberg engineers, the installation runs around the clock, six days a week, reducing costs and producing cleaner end products, brighter job finish, freedom from "decarb" and a consistently higher quality of work.

This is another example of how Lindberg equipment and Lindberg planning can help you find the most effective answer to any problem of applying heat to industry. We cover the field, heat treating, melting and holding, tempering, brazing, enameling furnaces, ceramic kilns, high frequency units, and are in the ideal position to recommend just the type of equipment most suitable for your needs. This can be factory built or field-installed in your own plant, fuel-fired or electric, whatever is best suited to your production processes. Consult your local Lindberg Field Representative (see the classified phone book) or get in touch with us direct. Lindberg Engineering Company, 2448 West Hubbard Street, Chicago 12, Illinois. Los Angeles Plant: 11937 S. Regentview Avenue, at Downey, California.

LINDBERG heat for industry

HOW KEY FORGING JET TURBINE TIGHT TEMPERATURE

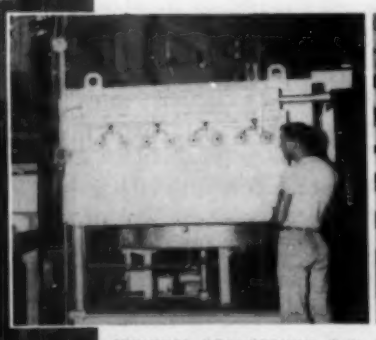
ELECTRIC FORGING FURNACES at Thompson Products, Inc. (Harrisburg plant), both General Electric and Hevi-Duty units, are equipped with GLOBAR heating elements to assure precise temperature control of alloys used for compressor and turbine vanes and blades. Shown above is one of several aisles in which both furnaces and forging presses are located.

PLANT BLADES KEEPS CONTROL

Jet Division of Thompson Products, Inc. uses GLOBAR® Delta electric elements for forging and heat treating

High temperature steels for a jet's turbine blades can be critically affected by variable temperatures during heating. That's why Thompson Products, Inc.—one of the largest manufacturers of rotating and non-rotating jet engine parts in the world—uses GLOBAR Delta electric heating elements. They assure close, precise temperature control to maintain the alloy's metallurgical properties.

At its Harrisburg, Pa. plant (shown here), Thompson Products, Inc.—long noted for its advanced techniques and materials—converts bar stock to completed turbine blades. According to Mr. Robert A. Buente, Superintendent of Maintenance, "furnaces equipped with GLOBAR elements do an excellent job. If we ever go to higher production rates, we'll use more GLOBAR-type furnaces."



TERMINAL CONNECTIONS (left) for 8 GLOBAR elements are on a HEVI-DUTY furnace. Elements can be replaced without cooling the furnace or interrupting production. **STOCK OF GLOBAR** Delta silicon carbide electric heating elements (right) is kept on hand to assure fast replacement.

ECONOMIC advantages of electric heat:

There are many reasons why the use of GLOBAR Delta silicon carbide elements are economical as well as dependable, clean, safe, and quiet. There is no fire or explosion hazard, and exhaust and fuel storage facilities—and costs—are unnecessary.

Only with electric heat can heating cycles be precisely duplicated and temperatures accurately controlled, independent of the atmosphere. Product quality is improved and rejects sharply reduced. Electric furnaces and kilns are compact and space-saving. They can be located in the production line, thereby accelerating production and reducing costs per unit of product.

When evaluating heat source, remember that electric heat alone utilizes its full potential. You don't pay for waste BTU's that go up the stack. Consequently, overall operating costs are reduced, furnace maintenance held to a minimum.

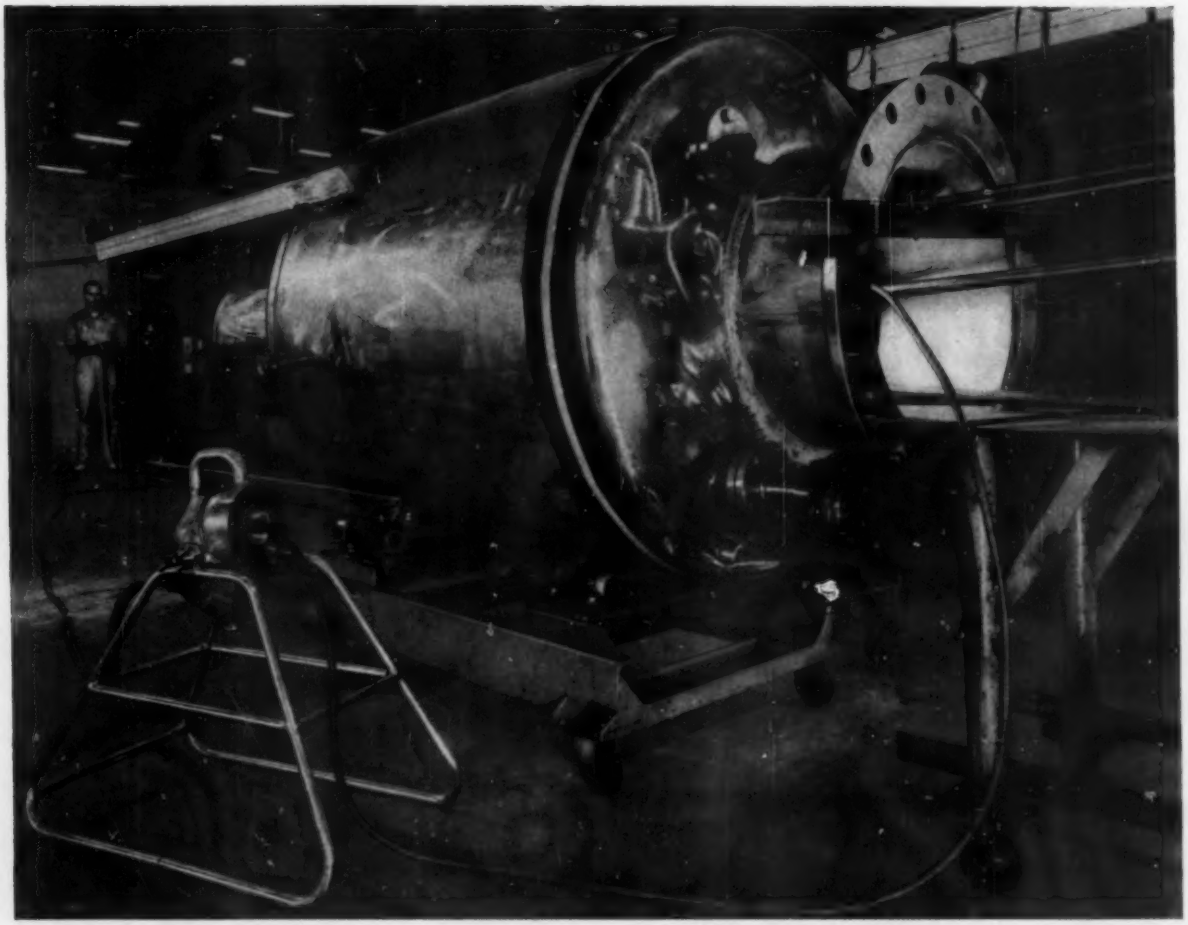
Installation of Delta elements is simple, and element replacement is accomplished quickly without cooling the furnace or interfering with production.

Typical applications for GLOBAR Delta elements include furnaces and kilns for: heat treating, forging, sintering, brazing, annealing, melting, assaying, roasting, laboratory and research; ceramic firing of ferrites, titanates, steatites, glass to metal seals, electrical insulators, grinding wheels, refractories, whiteware, pottery and tile.

Find out how your operation could profit by using GLOBAR Delta silicon carbide electric heating elements. Your furnace builder can supply you with full details. The Carborundum Company, Refractories Division, Globar Plant, Dept. MP89, Niagara Falls, New York.

CARBORUNDUM

Registered Trade Mark



OAK RIDGE NATIONAL LABORATORY USES NUCLEAR SYSTEMS' RADIOGRAPHY MACHINES

The Oak Ridge National Laboratory, operated by Union Carbide Nuclear Company for the United States Atomic Energy Commission, is using radiography machines developed and manufactured by Nuclear Systems, a division of The Budd Company, for inspection of nuclear facilities.

Shown above is an operator using Nuclear Systems' Model 30, checking a circumferential weld on a fabricated stainless steel pressure vessel, an evaporator used for waste disposal processing of radioactive materials.

Within 10 minutes the operator can make an *internal* exposure of a complete circumferential weld, using iridium 192.

Weighing only 55 pounds, the Nuclear Systems' radiography machine Model 30 is ideally designed for portability and in-shop exposures. Call on Nuclear Systems for your radiography equipment needs. Offices in Philadelphia, Chicago, San Francisco and Los Angeles. Sales representatives in principal cities. Catalog on request.

Visit our booth at the Instrument Automation Conference, Phila., Sept. 15-19.

NUCLEAR SYSTEMS
A DIVISION OF THE BUDD COMPANY, Philadelphia 32

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"WEIRZIN'S® ZINC-COATED SURFACE DEFIES CORROSION—TAKES PAINT BEAUTIFULLY!"

REPORTS LINCOLN METAL PRODUCTS CORPORATION, MAKERS OF BEAUTYWARE

A leading manufacturer of such housewares as kitchen canister sets, bread boxes, step-on cans and towel dispensers, Lincoln Metal Products of Brooklyn, N. Y., finds Weirzin electrolytic zinc-coated steel a natural for its purposes.

"Inventory problems are simply non-existent," says a spokesman. "You can store stamped-out parts of Weirzin indefinitely—even for years without worrying." Because its electrolytically fused zinc coating is so tight, not even the severest bending, drawing or crimping operation will flake or peel off its surface during fabrication. No exposed steel—no corrosion problem!

Also you'll discover—as have Lincoln Metal Products and many other users—that appearance is not the only beauty of chemically treated Weirzin's paintability: the economy of that lasting paint job is one of its biggest drawing cards, too.

In the market for a metal that combines strength, economy and super-resistance to corrosion? You'll find it eminently worth your while to investigate Weirzin.

Free Booklet "Weirzin" Gives Complete Details. Write to Weirton Steel Company, Dept. S-19, Weirton, West Virginia

WEIRTON STEEL COMPANY

WEIRTON STEEL COMPANY

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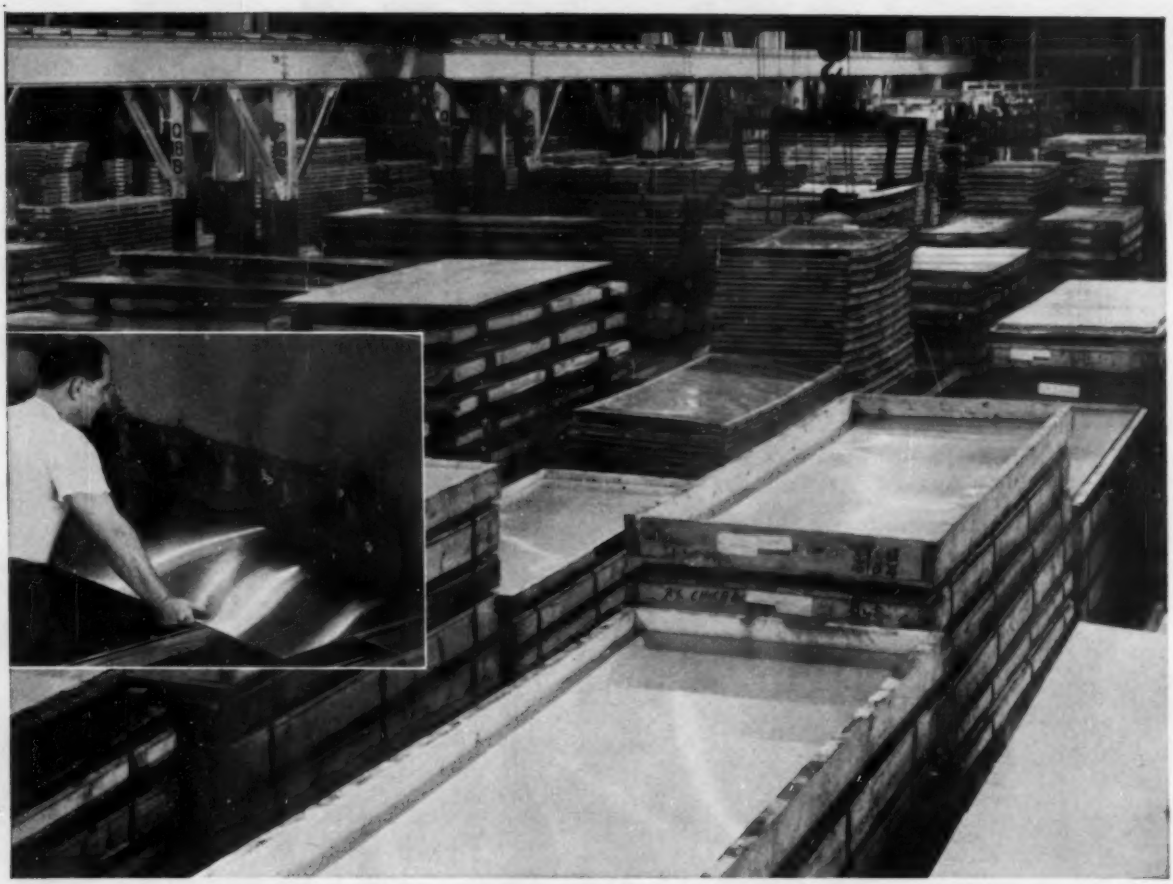

Why do more stainless buyers call Ryerson?

There are four main reasons:

First, the nation's largest stocks of Allegheny stainless are always on hand at Ryerson—2351 types, shapes, sizes and finishes . . . tons of sheets, plates, bars, angles, pipe, tubing and fittings.

Second, Ryerson knows stainless. As the pioneer supplier of stainless from stock, Ryerson has worked with more stainless users, helped more firms to use the right type to the best advantage. This experience is always available to present and future users.

Third is the equipment for cutting stainless to your specifications. The most modern shears, saws, and flame-cutting machines produce accurate sizes and shapes, in any quantity.

And fourth is Ryerson's ability to deliver any requirement, any quantity—on time.

When you need stainless, or help on stainless problems—call your nearby Ryerson plant.

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Metal Progress
Volume 74, No. 3 September 1958

Critical Points

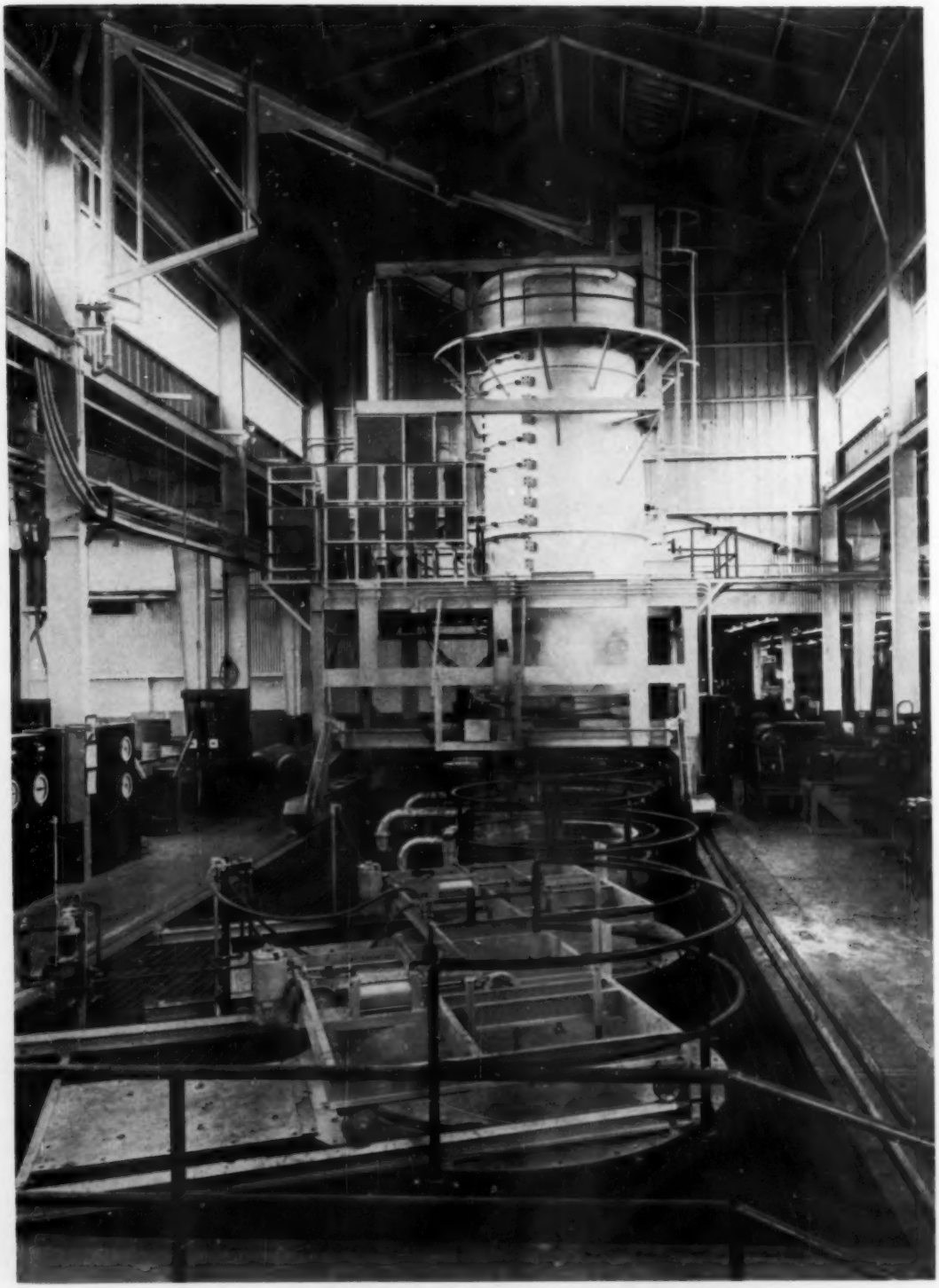
Heat Treating Rocket Cases

Most of you have seen a Nike missile site at one time or another. Have you ever wondered, then, what was inside one of those missiles? If so, be alert. What follows is a brief note about the heat treatment of a rocket case. This case holds solid fuel and naturally has to be quite strong since a tremendous pressure is exerted as the fuel burns. Furthermore, close tolerances are essential; building a missile is almost like building a watch.

To begin with, S.A.E. 4130 sheet steel, 0.110 in. thick, is formed into a tube and welded. After a cap is welded in place, the whole item is stress-relieved, and is then ready to be heat treated. Incidentally, all of this goes on at Goodyear Aircraft Corp. in Akron, Ohio, where Lindberg Industrial Corp. has installed the elaborate furnace setup shown in the photograph on the following page. The big cylinder at the far end of the shop is the heat treating furnace. As you can see, it is on wheels which run along rails; thus, it can be placed over any of the covered pits in the foreground. These pits are, beginning at the back, a salt bath quench of the nitrate-nitrite type which can be operated between 325 and 800° F., a water rinse operating between 180 and 210° F., and two tempering furnaces which operate between 400 and 1400° F. All control equipment, including transformers, contactors, and panels, rides on the gantry with the furnace while power and gas atmosphere lines follow the furnace through the boom at the top. Dry nitrogen is supplied by a generator behind the furnace.

In the photograph, the furnace is ready to receive a load (this can include either three 28-in. diameter cases or one 64-in. diameter case). Cases are loaded through the bottom and heated at 1600° F. to austenitize. After being shifted over the 350° F. salt bath, the cases are lowered rapidly to martemper. This takes about 20 min. Rinsing and tempering at 750° F. complete the treatment.

We were quite interested to learn that more than 20,000 rocket cases have been produced so far. With all of the international turmoil, it's pleasing to know that so much protection exists. God grant it never has to be used. C.R.W.



Gantry Furnace at Goodyear Aircraft Corp. Rides Along the Rails and Can Be Placed Over Any of the Pits. With this arrangement, rocket cases can be readily austenitized, martempered, rinsed, and tempered. The cases hold solid fuel for Nike missiles

Modern Attacks on Iron Ores

*By C. F. HOFFMAN**

While direct reduction will be applied commercially in some locations, it will not supplant the blast furnace, which is one of the most efficient metallurgical tools in use. To meet the increased future needs for more iron, steel mills will strive for higher production from existing furnaces by means of technological improvements. It has been estimated that, with beneficiated raw materials and with newly developed uses of oxygen and other techniques, production in the same size blast furnace used in 1940 can be increased 67%. (D1, D8, B16; Fe)

MODERN METHODS for reducing iron ore to metallic iron fall into two categories: direct reduction and use of the modern coke blast furnace.

Direct reduction processes have been recently revived after many years of failure due to technical and economic reasons. Only eight years ago, the idea of producing iron by direct reduction was rejected as being impractical. Although past attempts have been unsuccessful, they have value because a study of their history indicates what must be avoided for a successful process.

Economic considerations and the development of new techniques appear to be the reasons for their recent revival. As of the first of this year, U.S. annual blast furnace capacity was 91,000,110 net tons. It is estimated that by 1970 capacity will have to be increased to 120,000,000 net tons. This will mean the construction of some 50 new blast furnaces. With a new blast furnace and auxiliaries costing close to $40,000,000, it's easy to see why it is desirable to find alternative methods of reducing iron ore at a lower capital outlay.

Direct Reduction Methods

They can be divided into two areas: processes using the so-called fluidized solid techniques and those using more conventional equipment. The fluidized solids technique was developed for the petroleum industry. As adapted to ore processing, it consists essentially of a cylindrical reducing vessel filled with fine particles of iron ore through which a reducing gas (such as hydrogen or a mixture of hydrogen and carbon monoxide) is forced, causing the ore particles to act like a fluid, keeping them in a turbulent or boiling motion. Under proper conditions of temperature and pressure, oxygen is eliminated from the ore and the reduced metallic particles are then further processed.

Oxygen is the only element removed by this method. Ores high in silica, phosphorus and other elements will yield a product which is also high in such elements. These impurities must be removed by refining in some other metallurgical furnace. In some instances, the reduced iron powder may be concentrated by magnetic separation before briquetting.

Several variations of this means for direct reduction have been developed. The "H" iron process developed by Hydrocarbon Research and Bethlehem Steel Co. uses pure hydrogen at 900° F. and 400 psi. as the reducing agent. The Nu-Iron process of U.S. Steel is reported to use a mixture of hydrogen and carbon monoxide gas at about 1300° F. and 50 psi. The Esso-Little process is said to use a mixture of H, CO and nitrogen at 1600° F. and atmospheric pressure.

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*Superintendent of Blast Furnaces, Bethlehem Steel Co., Sparrows Point, Md. Mr. Hoffman is the 1958 recipient of the David Ford McFarland Award for achievement in metallurgy from the Penn State Chapter. This article is based on his address at the award banquet.

The Madaras process is also included in this type of reduction.

More Conventional Ways

Two methods of direct reduction use more conventional equipment: The R-N process (Republic Steel-National Lead), described in *Metal Progress* for April 1958, employs a long rotary kiln which is charged with a mixture of ore crushed to —1 in., crushed limestone and a carbonaceous fuel. The carbon in the mix is several times that needed for theoretical reduction. The kiln is fired with an oxidizing flame but the excess carbon in the charge is sufficient to achieve 90% reduction.

The product of the kiln is water quenched and crushed. The metallic iron is separated from the slag by wet classification and magnetic separation. Two kinds of product are made: a high-iron concentrate, which is pressed into briquets for electric furnace or openhearth charging, and a lean iron material, which is pressed into a shape suitable for blast-furnace feed. Unburned fuel is recycled. In this process, phosphorus in the original ore and sulphur in the fuel are largely eliminated. Obviously, temperature conditions in the kiln must be closely controlled in order to avoid clinkering and ring formations. Low-melting slags could be hazardous.

DLM Process

The second process is the DLM method (Dwight-Lloyd-McWane). The equipment used here is a pelletizing machine and a conventional sintering plant. The feed for the sintering machine is fine ore mixed with a large excess of fine coal, which has been formed into pellets. The pellets are sintered until about 6% carbon by weight remains in the charge. At this point, it is said that about 40% of the reduction of the ore has taken place and the carbon is transformed into graphite which binds the pellet materials together. The product is intended as feed for a blast furnace or electric furnace.

We feel certain that successful processes for direct reduction on a commercial scale will be developed, and in locations having access to ore of the proper grade, cheap fuel and electric power, or faced with other compelling economic considerations, full-scale direct reduction plants will be built. In integrated steel mills, we feel certain that direct reduction plants will not supplant present-day coke blast furnaces. However, they may implement the blast furnaces by providing a superior feed material.

Today's Blast Furnace

The modern blast furnace is one of the most efficient pieces of metallurgical equipment, both from the standpoint of thermal efficiency and utilization of materials charged. However, it's the aim of every operator to further increase this efficiency by means of increased productivity and decreased fuel requirements, both of which can reduce cost of the product.

The economic advantages of getting additional iron at a minimum coke rate from existing furnaces, so as to minimize the high capital cost of new blast furnaces, coke ovens, coal mines and stone quarries, are readily apparent. Approaches which are being followed to improve blast furnace efficiency are given below. The significance of each will be discussed.

1. Beneficiation of ores, including sizing and agglomeration of the fines for better gas-solid contact.
2. Improved coke quality, both chemically and physically.
3. Optimum slag composition — a result of better understanding of slag chemistry.
4. Moisture additions to the blast with higher blast heat.
5. Self-fluxing sinter.
6. Oxygen-enriched blast.
7. High top pressure.
8. Use of a super-rich iron burden from direct reduction processes.
9. Refractories.

Sizing and Agglomeration

Good gas-solid contact is of utmost importance for efficient furnace operation. All parts of the burden, as it passes down the stack, must be subjected to free and uniform flow of the furnace gases. This means the stock column must be reasonably free from channeling and size segregation. With variations in resistance to gas flow, in different parts of the cross section of the stock column, it's inevitable that there will be preferential paths of gas flow which give inefficient operation.

Screening, sizing and sintering of the fines will eliminate most of the size segregation in the stock column and will give better gas-solid contact. The result will be increased production and decreased coke rate. A conservative figure, which has been well checked, indicates that, for every 100 lb. of sinter used per ton of pig, there is a reduction of 8 lb. of coke.

Improved Coke Quality — Washing of coal at the mine to reduce ash content and possibly

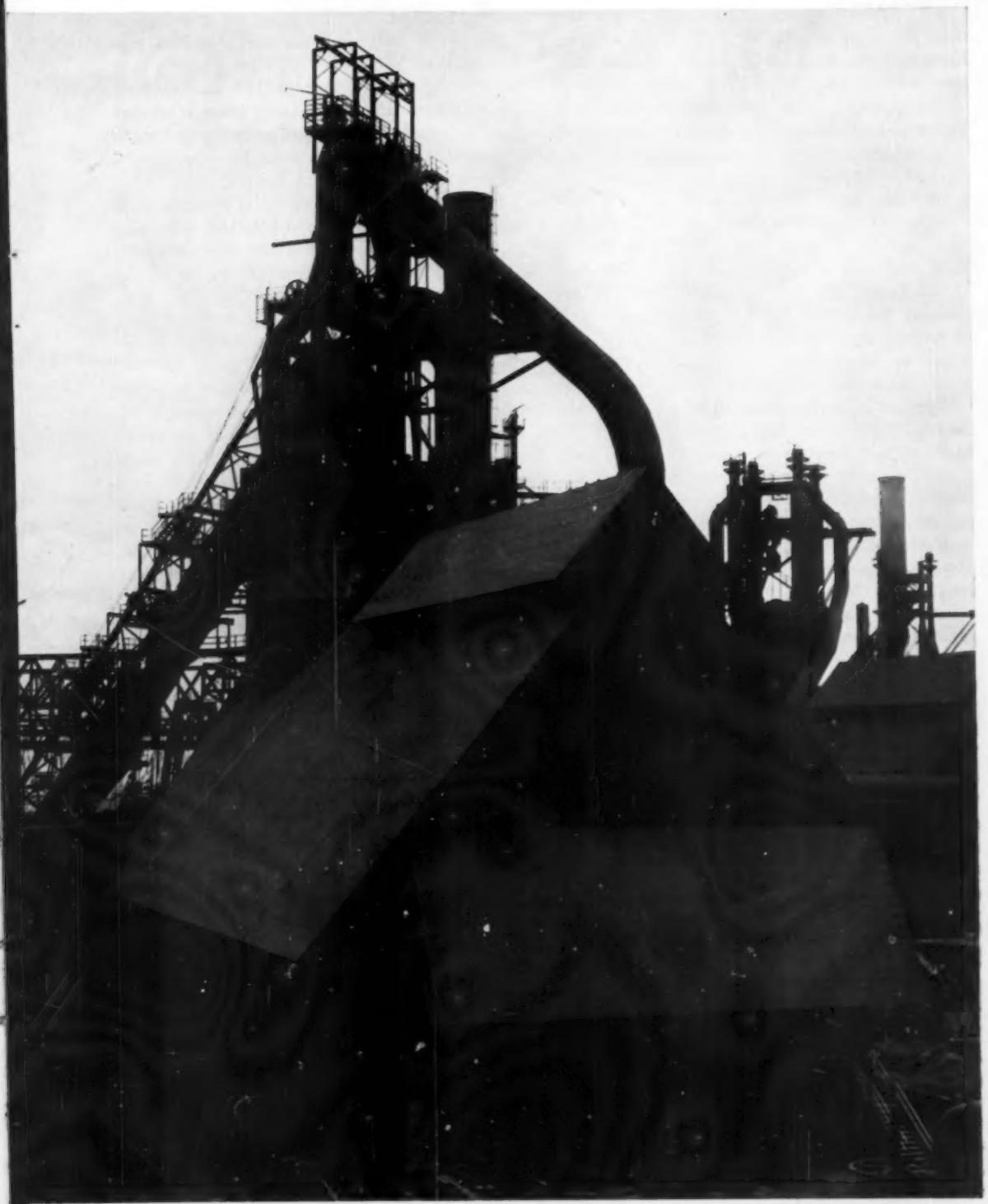


Fig. 1 – Beneficiated Raw Materials, New Uses of Oxygen and Other Techniques Can More Than Double Production From the Blast Furnace Compared With What Was Obtained in 1940. (Photo courtesy Bethlehem Steel Co.)

lower sulphur, coupled with fine grinding at the coke plant, gives a strong coke which enables blast furnaces to carry a heavier ore-to-coke ratio, with reduced slag volume. The work done at Pennsylvania State University leading to a better understanding of the mircroconstituents of coal and their relation to coke quality has been of great value here.

Optimum Slag Composition – A better understanding of slag chemistry resulting from the work done at Pennsylvania State University by E. F. Osborne, R. C. DeVries, K. H. Gee and H. M. Kraner has been most beneficial. It has enabled the furnace operator to produce a slag of such composition that a wide latitude of variation in composition is possible, without a troublesome slag developing.

Moisture Additions to the Blast – Many operators making controlled moisture additions to the blast report smoother-working furnaces with better gas-solid contact which results in increased output. The Russians report a 5% increase in production for each 8 grains of moisture with about 2% reduction in the coke rate. Here is a summary of their experience with humidified blast: The efficiency of the blast furnace rises, as the absolute humidity increases, providing the temperature of the blast is raised to make up for the heat expended on decomposing the moisture. The use of humidified blast improves the reducing power of the gas; for each 4.34 grains of moisture per cu.ft. in the blast, the hydrogen content of the bosh gas is increased by 1%. Increase in blast temperature to compensate for heat lost in decomposing the moisture is about 30° F. for each grain per cu.ft. of moisture.

Self-Fluxing Sinter – This technique appears very promising. In making self-fluxing sinter, the limestone, which is normally charged into the furnace to flux the impurities in the ore, is added in a finely crushed form (⅛ in.) to the sinter mix. Thus, the furnace does not have to calcine the stone. This results in a decreased slag volume and decreased solution loss. The over-all result is increased production of iron at a lower coke rate.

One operator reports 31% more production from the use of sinter containing a high percentage of calcium oxide. Another reports 17% more production and an 18% decrease in coke rate. In this case, not only the stone required for the ore, but also the stone required for the coke, is incorporated in the sinter mix. No raw limestone is charged into the blast furnace. The Russians report that, by going from a burden made up of 20% regular sinter plus 20% self-fluxing sinter to an 85% self-fluxing sinter, they have increased iron tonnage 14% and reduced the coke rate 11%. Self-fluxing sinter is weaker than a normal sinter so that probably its use, to obtain maximum benefits, must be accompanied with elevated top pressure blowing.

Oxygen - Enriched Blast – Experiments with the use of oxygen-enriched blast on a furnace producing basic iron have not been encouraging. On the other hand, the use of oxygen in the production of ferromanganese has been very encouraging. Here, a combination of tools, oxygen-enriched blast plus moisture additions, may give the desired result.

High Top Pressure – The volume of wind which can be blown into a blast furnace for optimum performance is a function of the velocity of the gases through the voids of the stock column. If more wind than this is blown, more flue dust results, together with poor gas-solid contact. By increasing the top pressure, more wind can be blown and optimum velocity of the gases still maintained with decreased flue dust production.

For example, a furnace operating at 30-lb. blast pressure and 12-lb. top pressure should be able to blow 25% more wind than a conventional blast furnace and still maintain the same velocity of the gases through the stock column. Current reports on high top pressure operation indicate an increased production of 6 to 10%. Other advantages: a smoother working furnace, less flue dust, and more uniform analysis of the product.

Super-rich Iron Burdens – Charging the blast furnace with the product from a direct reduction process (iron content of 80% with much of it in the metallized condition) would increase iron output tremendously and reduce fuel requirements substantially.

Refractories – Constantly improving refractories – both ceramic and carbon – must be given full credit for the steadily increasing life of blast furnace linings. The carbon hearth has been largely responsible for reducing the number of hearth breakouts.

Summary – It has been estimated that with beneficiated raw materials and newly developed uses of oxygen and other techniques, production in the same size blast furnace used in 1940 can be increased 67%. The reported Russian production of 2500 tons per day on a 26½-ft. blast furnace appears to bear this out.

Forging Blooms From Ingots

*By JOHN E. DECKER**

A short, heavily tapered ingot is forged after the piped zone is isolated from the sound steel by a punch. Tests show the blooms to be sound and free from segregation. (F22, D9k; ST, 4-52, 5-59)

AN INTERESTING NEW PROCESS now in production makes it possible to forge ingots weighing up to 8100 lb. directly into blooms. This method, invented by George A. Dornin, employs ingots of radical design which are upset-forged on 2500-ton presses. It produces an exceptionally clean, homogeneous product since the heavy segregated zone in the hot top vicinity is isolated from subsequent working at the start. Yields of 80% from ingot to shipped billet are possible.

As background, a discussion of conventional hot-topped ingots for killed steel is in order. Generally, such molds are big-end-up with an inserted clay hot top. They have a slight taper to aid extraction of the ingot and to promote freezing from bottom to top. However, the taper cannot be too large since the ingot has to enter the blooming mill rolls readily.

One common method in pouring such ingots is to pour to the bottom of the hot top and wait until a seal freezes between hot top and mold. While waiting, the body of the second ingot is often poured. Meanwhile, the steel surface at the bottom of the first hot top cools off and may crust over completely. When the hot top is finally filled, the stream melts this crust at the center but seldom over the entire surface. If crusting occurs, secondary pipe and segregation are usually present inside the ingot. Equally serious are nonmetallic inclusions. Heats perfect in the furnace are often contaminated from refractory material picked up by the time ingots are poured. Fortunately, inclusions are lighter than steel and rise to the top if given the chance. However, when the hot top is poured, the stream may drive the inclusions back into the ingot, and many of them can be trapped as the ingot cools. In a standard killed steel ingot, the last metal to solidify – that directly under the pipe cavity – is highly segregated and practically useless.

Since our ingot is not rolled, but forged, it can be patterned strictly for elimination of segregation. Accordingly, it is made short and squat (only 2½ times length over diameter), with a 12½° taper – about three times that normally used. As this heavy taper makes better bottom-to-top freezing possible, the hot top, a prime inclusion source, is no longer necessary. Its absence removes the possibility of hot-top brick spalling; seal leaks and hanger cracks resulting from them are also eliminated. Further, there is no interruption in pouring, and thus no chance to drive inclusions back into the ingot. After pouring, insulation is applied to the top to aid in keeping the pipe cavity shallow. Ingots are kept in molds until charging into the soaking pits.

Forging the Ingot

Since the main object is to isolate the segregate zone, the forging process begins with this step. The ingot (Fig. 1) moves to a vertical, cast iron holding die mounted on a 2500-ton upsetting press. A hollow, tapered steel punch (Fig. 2) is driven down to the bottom of the segregate, thus separating the inclusion-filled core from the sound steel. Two successive upsetting dies then force this surrounding good metal below the core bottom. Figures 3 and 4 illustrate this action. Now that the segregated zone is isolated, the mushroom-shaped ingot can be forged. Vertical upsetting has increased the ingot cross-sectional area by 94% and altered the entire cast structure.

The next forging operation (Fig. 5) reduces the 39-in. bulge to a 16-in. square – a reduction of 4.7 to 1. Since this bulge includes about 60% of the ingot, the working, grain refining effect is extensive. Figure 6 pictures the completed bloom; it is now ready for hot scarfing, further

*Chief Metallurgist, Green River Steel Corp., Owensboro, Ky.

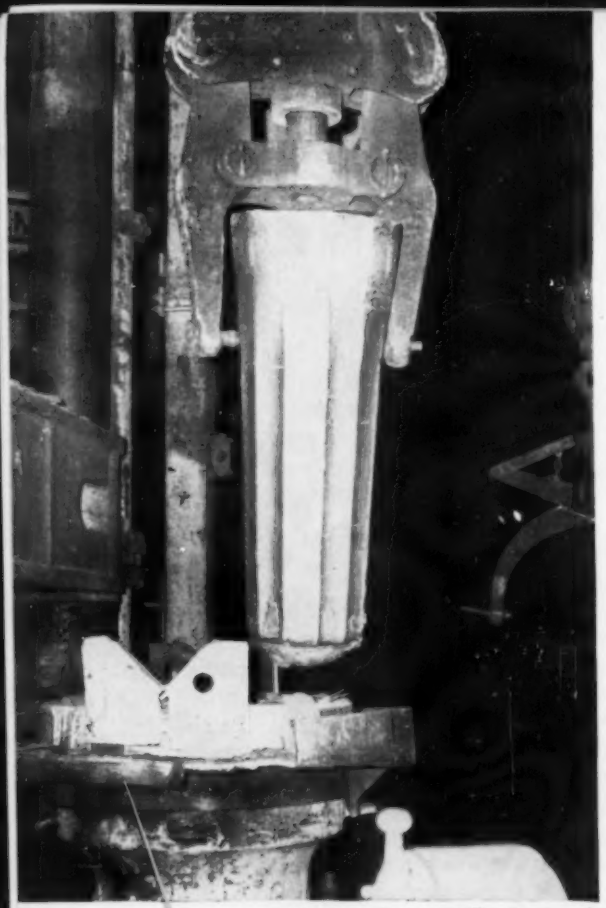
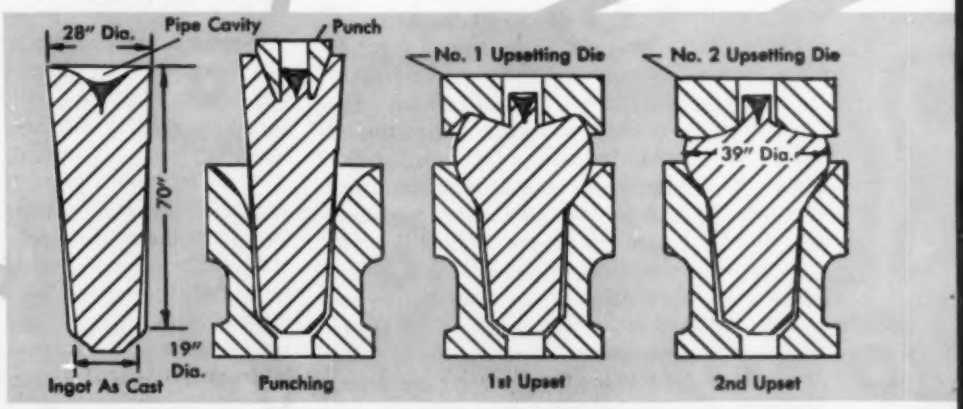


Fig. 1—The Specially Designed Ingot, Having Left the Soaking Pit, Approaches the Vertical Die

Fig. 2—The Segregated Core Is Separated From the Sound Steel by the Punch



blooming and removal of the segregate tip. Final rolling to the finished product follows. The central diagram illustrates changes in shape occurring from ingot to bloom.

Our tests on these forged blooms have revealed remarkable results. Transverse physical properties and cleanliness have increased appreciably. Furthermore, we have found that steels heat treated to ultra high strength levels (260,000 to 280,000 psi. tensile strength) are consistently well above the transverse ductility requirements. Values of transverse reduction of area at half-radius consistently exceed the minimum 10% for cross sections greater than 100 sq.in. and 15% for smaller sizes.

We feel that our results prove that the combination of a special ingot design with extensive forging produces a superior product.

Fig. 3—The First Upsetting Forces the Steel Away From the Core

Fig. 4—The Segregated Core Is Completely Isolated From the Sound Steel by the Second Upsetting Operation

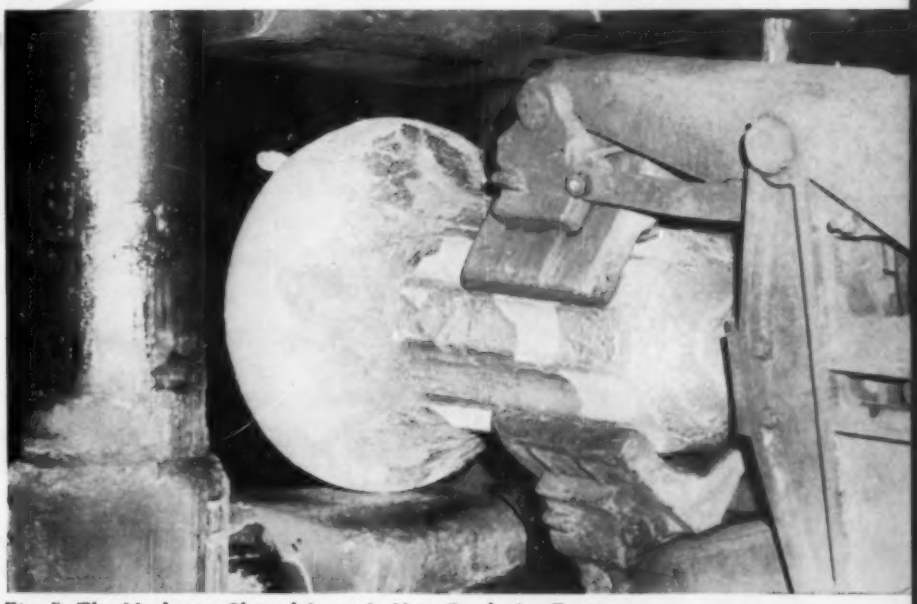


Fig. 5—The Mushroom-Shaped Ingot Is Now Ready for Forging

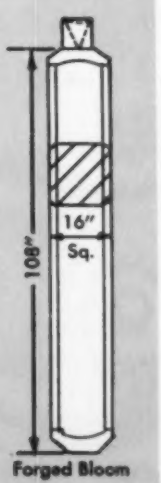
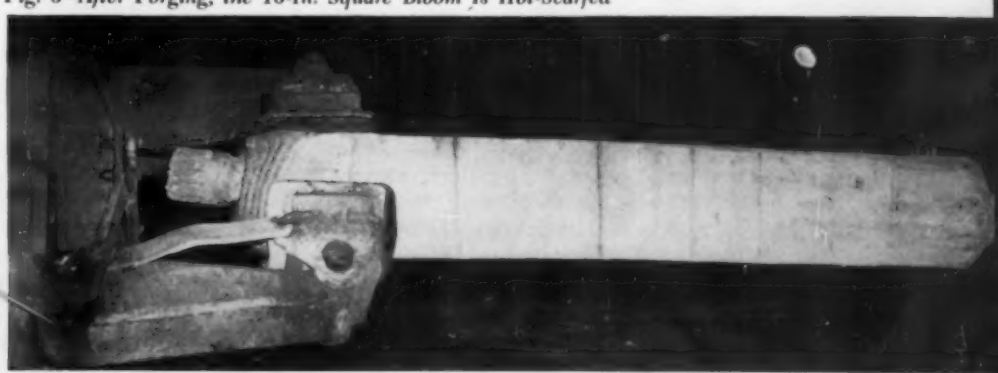


Fig. 6—After Forging, the 16-In. Square Bloom Is Hot-Scarfed



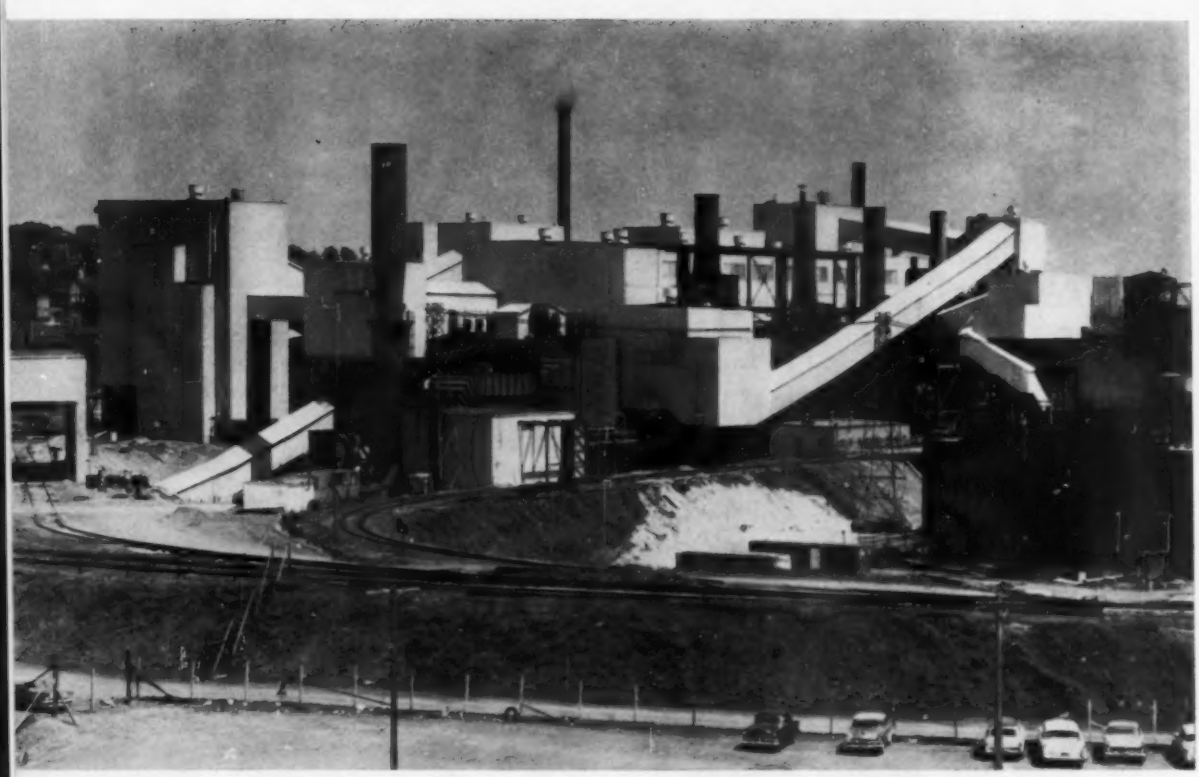


Fig. 1 – View of New Sintering Plant at Youngstown, Ohio. It produces 5000 tons of iron ore sinter every day when at capacity operation

Sintering: 5000 Tons a Day!

United States Steel's new sintering plant is virtually automatic in operation. The strong porous cake provides a more effective blast furnace burden. Furthermore, the ore supply is indirectly increased because fines formerly lost are used to make the sinter. (B16a, D1; Fe)

DISCOVERED – a practical use for flying saucers! As mixers and pelletizers of the fine ore-fuel blend to be sintered, they are the mechanical heart of the new 5000-ton per day Dwight-Lloyd sintering plant built by McDowell Co. for the Ohio Works of United States Steel Corp. These "saucers", which are essentially inclined rotating pans, are only one of several innovations making this one of the most modern sintering operations today. The product of this giant building (see Fig. 1) is intended to feed the five blast furnaces at Youngstown; its users

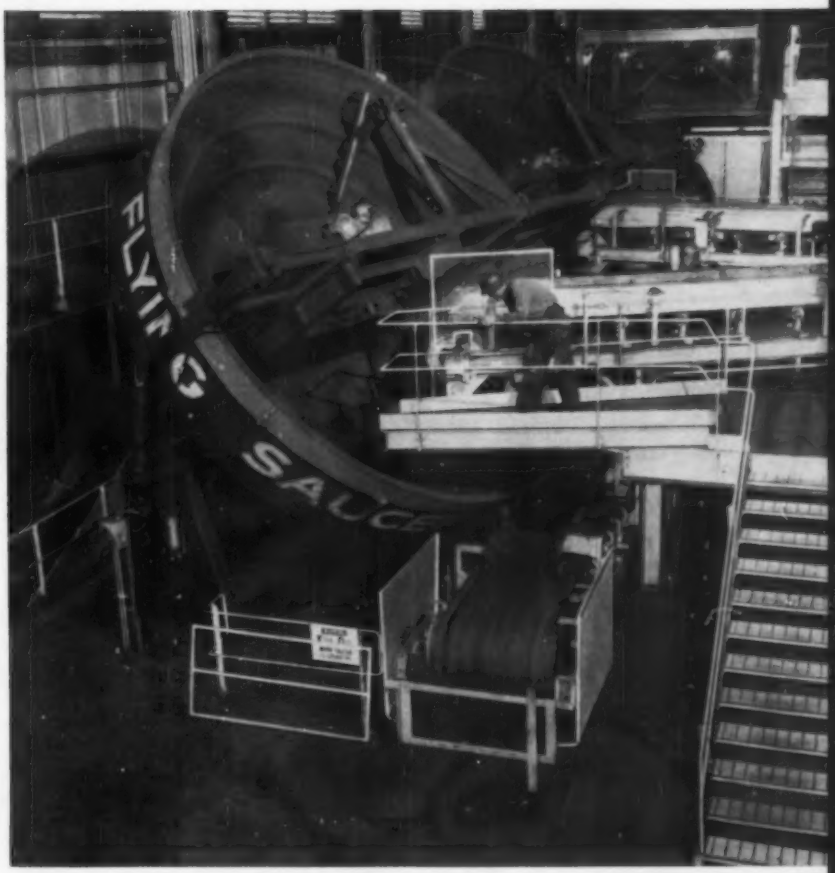


Fig. 2 – These Constantly Turning Pans Pelletize the Mix. The tumbling, folding action insures a homogeneous product for sintering

believe the strong, porous, uniformly sized sinter cake will enable furnace operators to obtain greater efficiency and produce more iron.

The Process

Sintering is not new. Fifty years ago, Dwight and Lloyd devised their first continuous sintering machine to convert nonferrous ore fines into a product suitable for further refining. The basic features of the process – and the product – are the same today as they were then. As originated for copper ores, sulphide fines were distributed in a thin layer along a traveling belt made up of grates. Ignition followed, and the sulphur was burned out of the ore with air drawn through the layer by large fans. A strong cellular sinter cake, desirable for reverberatory and blast furnace charging, was the result. In nonferrous sintering, the fuel (sulphur) is self-contained; in iron ore sintering, the fuel (carbon, in a finely divided form) has to be added. This is the basic difference between the two.

Since the heart of the sintering process lies in the thin-bed principle, production can be increased by merely widening and lengthening the traveling grates carrying the bed. The other equipment can be easily scaled up in size. This, of course, has occurred continually from the time the prototype 25-tons per day plant at Salida, Colo., was started. Today, with plants 200 times bigger in operation, Dwight and Lloyd would have trouble recognizing their brain child.

The Plant

The plant at Youngstown is virtually automatic in operation. Controlled by a gigantic centrally located panel board, huge belts, totaling more than 1½ mi. in length, convey material throughout the operation. As the diagram in Fig. 3 shows, the work begins with the arrival of ore at the yard. After screening, to separate coarse ore for the openhearth and medium ore for the blast furnace, ore fines travel to hoppers for subsequent mixing with coal fines. Optionally, flue dust may be added. Automatic proportioning makes possible close control of composition.

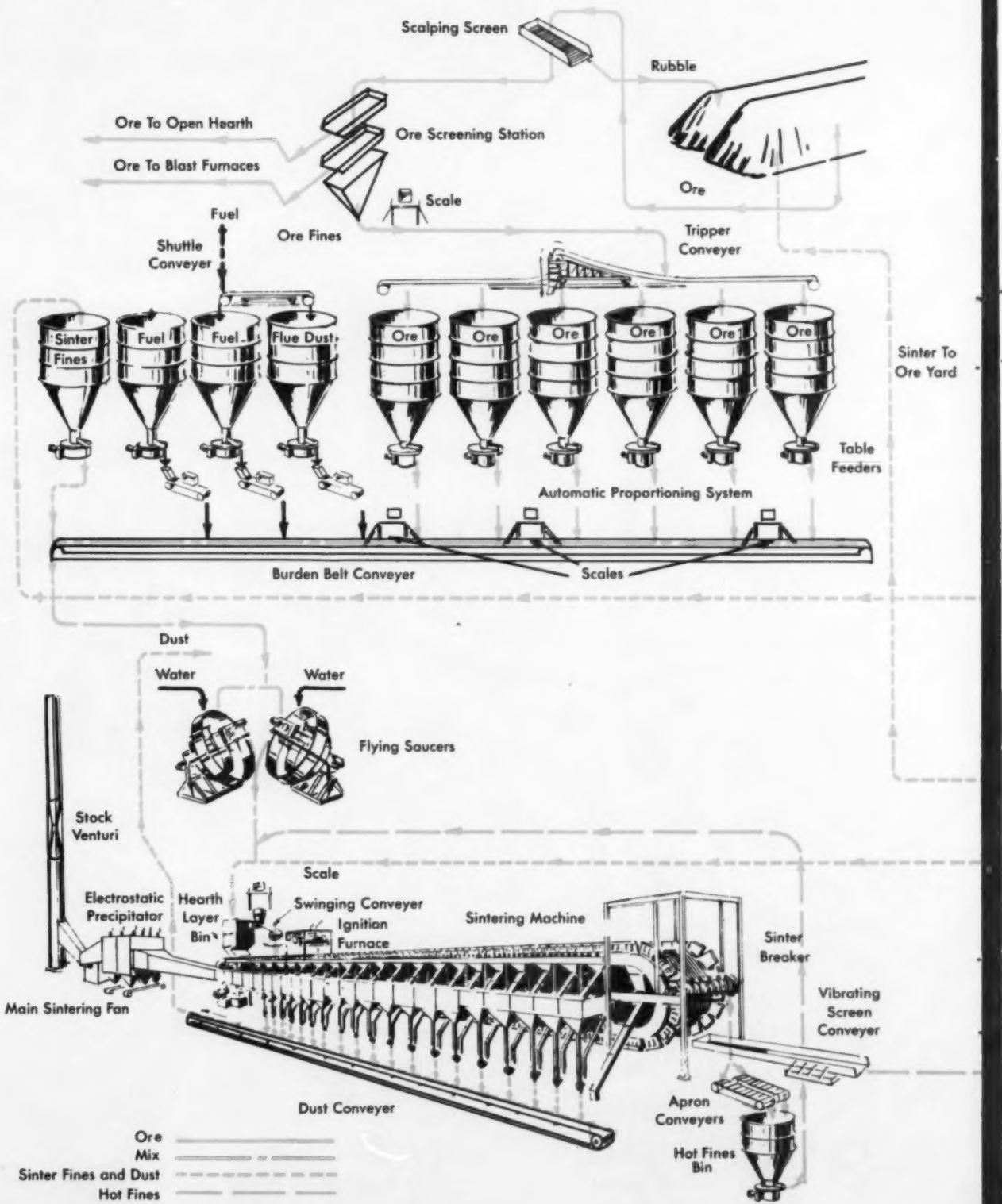
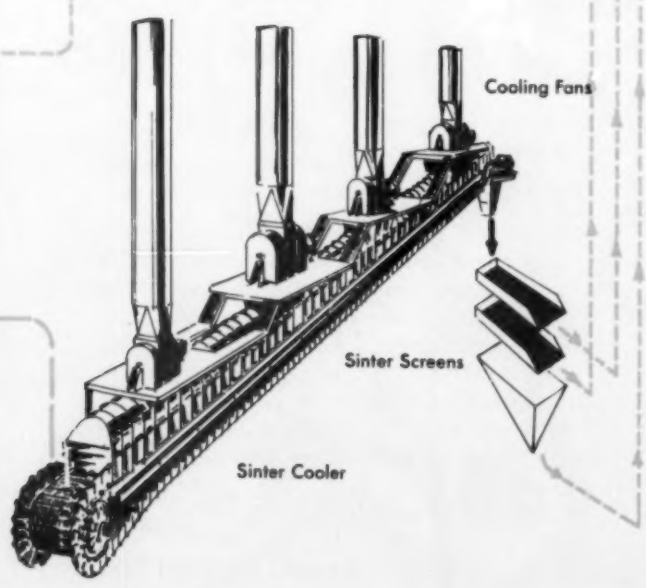


Fig. 3 – Diagram of Features Contained in Plant. Note that all operations are interconnected so that all dust produced is recycled through the sintering machine

By conveyer, the mix now travels to the "flying saucers". The ore fine-fuel mix falls into the continuously turning pans (Fig. 2) to be thoroughly blended by tumbling with sinter returns. As the "saucer" revolves, a controlled water addition provides enough cementing to form small pellets. These homogeneous pellets spill constantly from the "saucer" lip into the swinging conveyer; they provide the porous burden needed for proper sintering action. In the meantime, sinter fines arrive continually from the cold end of the sinter cooler. These nut-sized pieces are distributed along the conveyer before the burden is deposited. This cold sinter bed – called the hearth layer – insulates grate bars, prevents burden loss and grate bar plugging, and aids separation of the newly formed sinter from the bed at the discharge end of the conveyer. The pelletized burden is laid over the hearth layer and travels into the ignition furnace where the included coke is set afire. This ignition area is small since most of the sintering machine is taken up by windboxes below the conveyer which pull large volumes of air through the burning sinter bed to maintain ignition. When the sinter leaves the machine, it is broken up, screened, and passed over to the cooler where fans drop the sinter from 1100 to 250° F. in less than 300 ft. When cooled, the sinter is again screened. Heavy pieces go to the ore yard or blast furnace, small pieces to the hearth layer, and fines to the sinter burden conveyer.



The Controls

The above is a simplified version of the Ohio Works setup; numerous other operations, all dovetailed through the control center, also take place. For example, the main sintering fan which draws the gases from the machine through the electrostatic precipitator and into the stack has an important function. The stack itself has a venturi section at which the gas composition is determined to enable better control of the sintering operation. Each feeder delivering material from the bins is separately controlled and synchronized. Factors such as fuel consumption, draft, flow, and product output, all of which contribute to better efficiency, are constantly recorded. In addition, separate controls for nine major flow lines (incoming ore, flue dust, fuel, rubble, hearth layer, hot returns, cold returns, dust and sinter) are maintained. The control center contains a television circuit through which the discharge end of the sintering machine can be observed. An experienced operator is able to judge the quality of the product and the general sintering conditions without moving from the controls. A complete schematic of the plant with lights to indicate equipment in operation and flow of material is against the wall. The supervisor of this complex nerve center can converse with anyone in the plant through a two-way loudspeaker system. When in operation, this electrical equipment makes it possible to run the plant solely from the air-conditioned control room.

Sintering methods in today's high production climate are moving forward rapidly. In producing an extremely satisfactory blast furnace burden from virtually useless ore fines, sintering effectively increases blast furnace capacity. Not only does the porous burden allow a greater, more efficient blast, but less coke is needed for reduction. Calculations indicate that the capacity of each furnace can be raised 25%; sintering, in effect, adds another blast furnace to the line.

As time passes, the sintering process will probably be used more and more. The constantly increasing production of iron will make it necessary to mine leaner ores which will have both a smaller percentage of iron and a greater amount of fines. Sintering has had a great past; it is likely to have a more brilliant future.

Mechanized Austempering of Steel Harrow Disks

Parts are heated at 1575° F. in a neutral salt bath for 1.6 min., then austempered at 750° F. in a nitrate salt for 6 min. The bainitic structure obtained prevents directional cracking. (J26p, 18-74; ST)

AUTOMATIC AUSTEMPERING has almost doubled production of harrow disks at the Hamilton, Ont., Works of International Harvester Co. of Canada, yet uses only about half the man power formerly required. The installation, shown schematically in Fig. 1, processes 450 18-in. steel disks per hr. compared to 250 obtained by the former controlled-atmosphere oil quench method.

The new unit combines two Ajax-Hultgren salt-bath furnaces with wash and rinse tanks and uses a jack-rabbit push-pull mechanism designed for this particular job by Ajax Electric Co., Philadelphia.

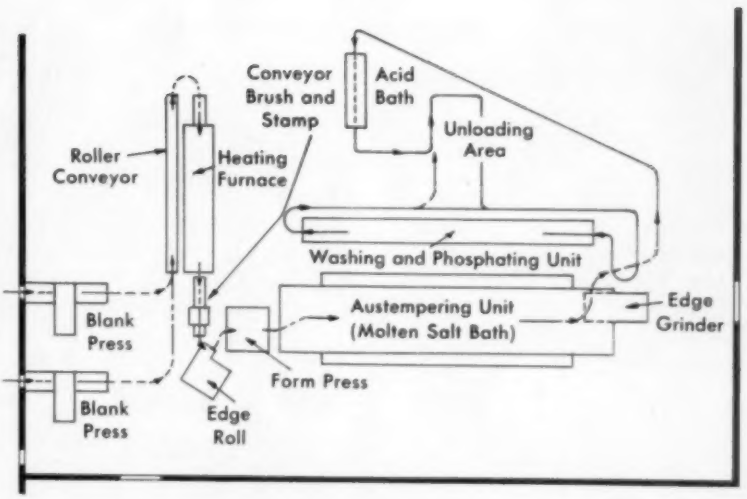
It takes only about 1 hr. to turn a high-carbon steel blank into a disk. Based on an hourly capacity of 4500 lb. (450 disks), International Harvester can now produce a million disks a year with the new equipment.

Sequence of Operations

Aside from hand loading and unloading the conveyers, the entire process is automatic. Prior to austempering, round disks blanked out of hot rolled steel sheet are carried by a roller conveyer to a conventional furnace where they are brought to 1800° F. Coming out of this furnace, they are fed to an automatic edge roller and a form press which gives them their concave shape. Here the part number, heat number and date are stamped on them.

Disks are then hand-fed to fixtures which automatically convey them through the entire austempering process. Three disks suspended from

Fig. 1 – Layout for Producing Harrow Disks by Austempering Method

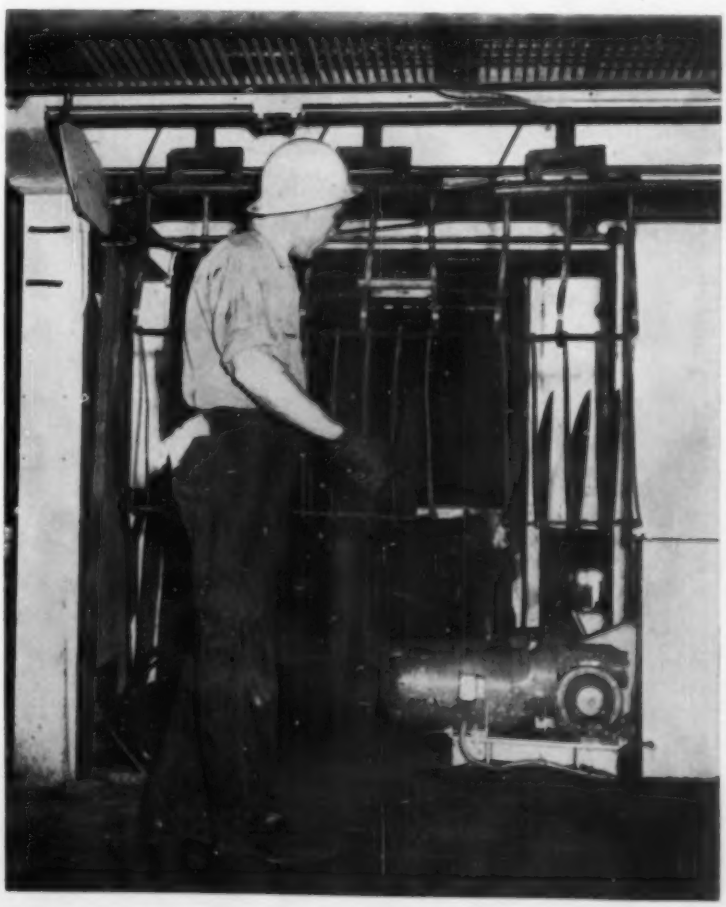


each fixture are kept well separated for maximum heat treating efficiency. At the first stop, disks are immersed for exactly 1.6 min. in a neutral mixture of potassium chloride and sodium chloride maintained at an even temperature of 1575° F. in all parts of the bath. This timing is very important and is automatically controlled by the conveyer mechanism. The ceramic tile pot for this furnace has a working length of 99 in. and is 24 in. wide with a salt-bath depth of 29 in. Heating capacity of the furnace is 540 kw.

The next step is austempering at 750° F. for 6 min. This uses a 243-kw. two-chamber quench furnace containing a nitrate salt. The quench chamber is 236 in. long by 24 in. wide with salt depth of 45 in. The separating chamber is 45 in. long by 36 in. wide and has the same depth. It operates at a slightly lower temperature which permits the chloride salts carried over from the neutral austenitizing bath to precipitate for removal.

From here, the parts are automatically suspended to allow them to air cool for 1.6 min.; then they are dipped into a wash-rinse tank for 3.2 min. This completes the austempering phase of the process. Final finishing operations include sulphuric acid pickling and phosphate coating to guard against rusting.

Fig. 2 – Operator Takes Disks From Forge and Fixtures Them on Conveyer for Salt Baths. Entering temperature from forge is 900° F. Loading and unloading are the only manual operations



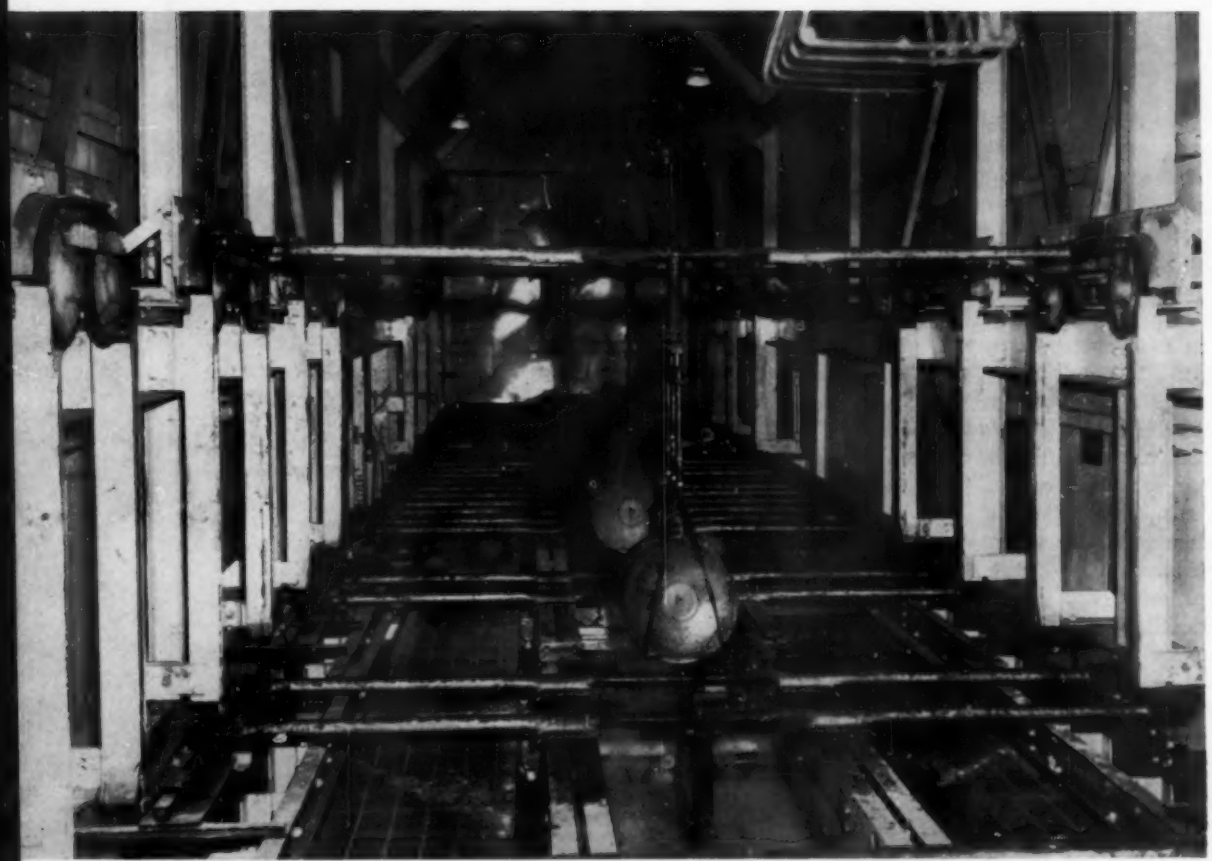


Fig. 3 — Interior View of Mechanized Austempering Unit. The line consists of a neutral salt bath, a nitrate salt quench, wash and quench tanks

Properties Obtained

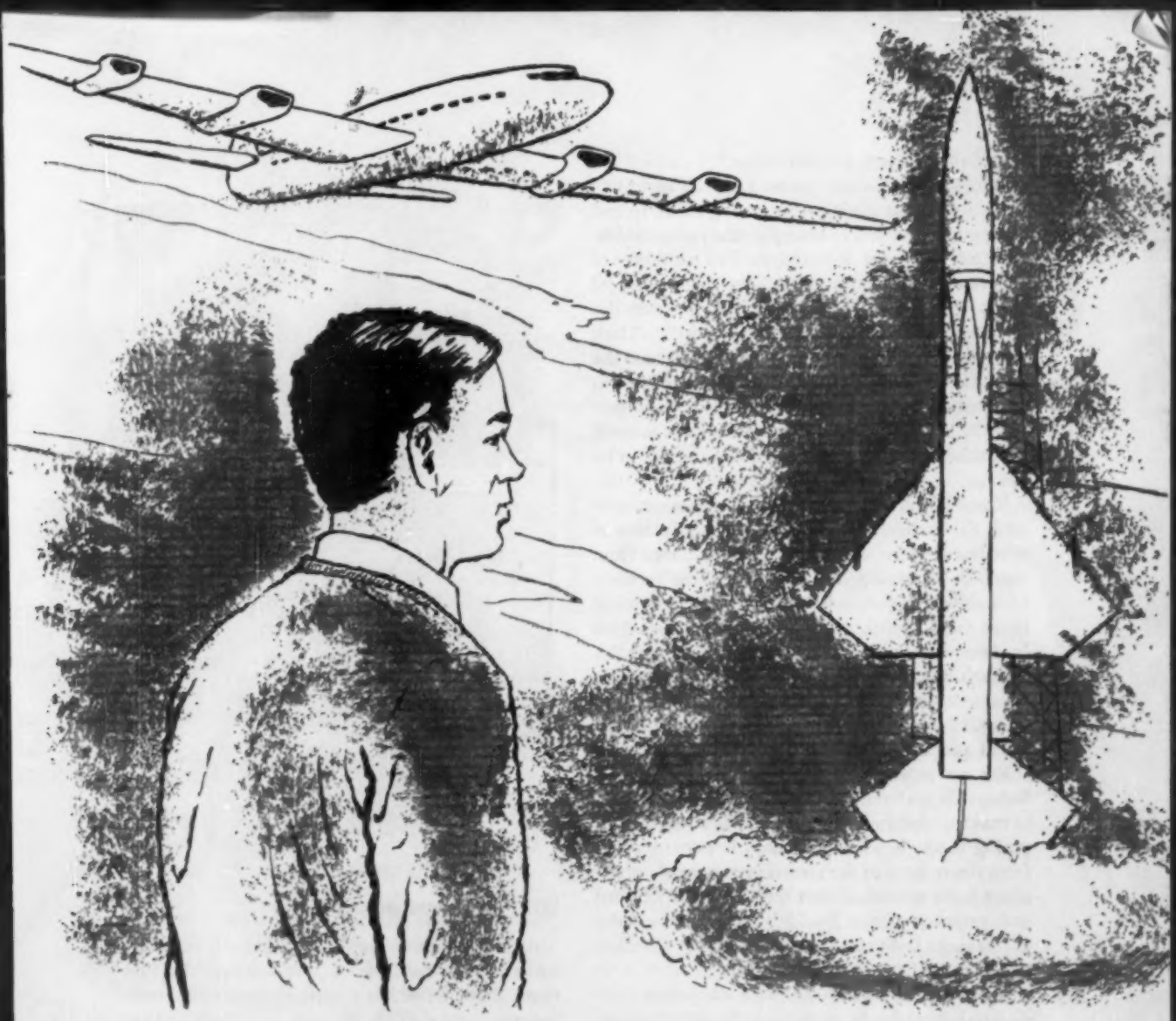
Disks are austempered within hardness limits of Rockwell C-38 to 42 without cracking or distortion. The bainitic structure obtained eliminates directional cracking.

When oil quenched and tempered by conventional methods, parts such as these produced from a straight rolled sheet have a tendency to crack, with cracks running in the direction of rolling. The bainitic structure prevents this.

The austempered disks have a superior finish. Rejects due to distortion have been cut 50%. Under the old system, disks were heated and maintained at a cherry red for a specified time. After oil quenching, they were reheated for tempering in a controlled atmosphere. Extensive tests including field trials have shown that the austempered disks last longer because they are tougher and less likely to fracture.

Conveyer Mechanism

The jack rabbit, a vertical chain conveyer, transfers disks from one operation to the next. The push-pull mechanism moves work through the neutral austenitizing bath and consists of two parallel beams with reciprocating push-pull bars and dogs. These beams run the length of the complete unit, one on each side. The push-pull bars are operated by hydraulic cylinders and carry the dogs. Dogs are arranged to advance fixtures at the center of the furnace only a part of each stroke, while end fixtures are advanced the entire stroke. This gives closer spacing of the work at the center and wider spacing at both ends to facilitate loading and unloading. The push-pull mechanism permits the use of a shorter austenitizing furnace. Heat losses are minimized, floor space conserved, and salt and power consumption reduced.



Many Metallurgists Still Needed!

Visualize the world without metal and what strange primitive conditions you would see! No automobiles, no airplanes, no television, no refrigerators. Even frying pans and table knives would be unknown. We would be back in the Stone Age!

Nature blessed us with about 65 metals, each different in some way from the others. Our grandfathers knew of about 16, and in ordinary life had seen fewer than that. Today, almost the whole 65 are in use somewhere, and man is not content with the 65; he must make new ones, some of which never before existed on earth unless for perhaps a fleeting instant when the earth first became compacted in the shape we now know it. We are speaking here of the metallic *elements*, not alloys which are mixtures of two or more elements. The alloys in every-day use number in the tens of thousands, and make a real problem for the design engineers who must decide which is the best to use.

The men who have made this vast array of new

Take this insert out and give it to some bright boy who is still in high school or who has just graduated. Also try to sell him on your profession.

materials available are known as "metallurgists". While Mother Nature gave us the 65 metals to use she did it grudgingly, so mixing them up and compounding them in ores that the metallurgists' greatest ingenuity is taxed to find methods of separating and extracting them into a useful form. The people who do this work are in the field known as "extractive metallurgy". Their concern is the production of pure metal from the ore as it comes from the ground (and at least in one instance out of sea water!) However, getting the metals in the pure state does not in itself make them useful. Much more work needs to be done.

The "physical metallurgist" then takes over from the "extractive metallurgist". He is the one who has to know why one metal is different from another. Knowing this, he knows how to combine different metals in alloys in order to make them more useful. By studying their behavior he knows how he can improve their properties through working them in rolls or under forging hammers, or by giving them special heat treatments. Almost every service requires a different set of properties.

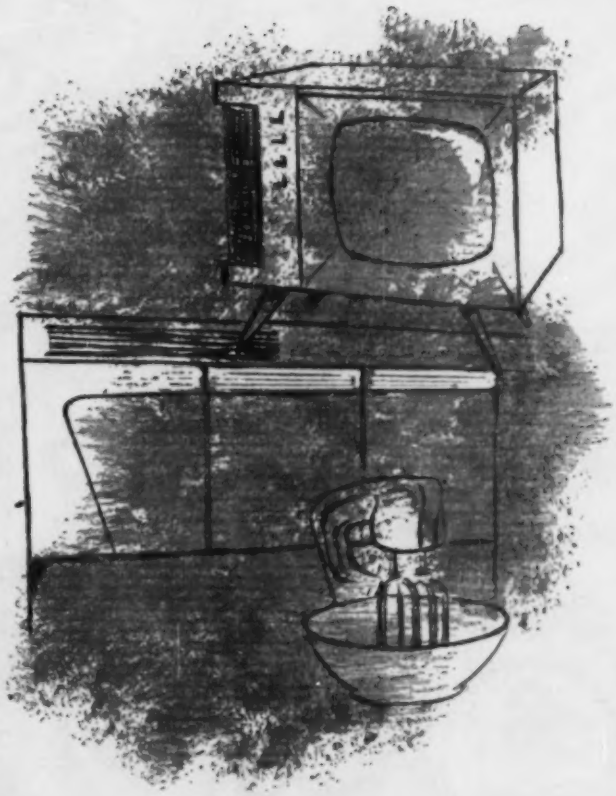
For an example, in atomic energy work the fissionable materials must be diluted by alloying to make usable fuel elements; the heat-exchanger piping through which the heat is carried away from the reactor to the electric generating equipment must withstand not only the temperature and pressure of the liquid but must also resist the damage from the enormous amount of radiation coming from the fuel element.

In missiles, what covering and what nose cone material must be used to take the intense heat generated by friction with the earth's atmosphere, and also the extreme temperature of the ionosphere? Meteorites are intensively studied, for they have had that experience and have solved the re-entry problem.

In recent automobiles, what material should be used in a torsion bar that bump after bump for millions of bumps must not stiffen and become brittle, nor relax and become weak, causing breakdown and even injury?

Commercially pure iron is an ideal material for forming automobile bodies, but would be useless in engine parts. For these the iron must be alloyed to make steel of the high strength needed for springs, gears, connecting rods and crankshafts.

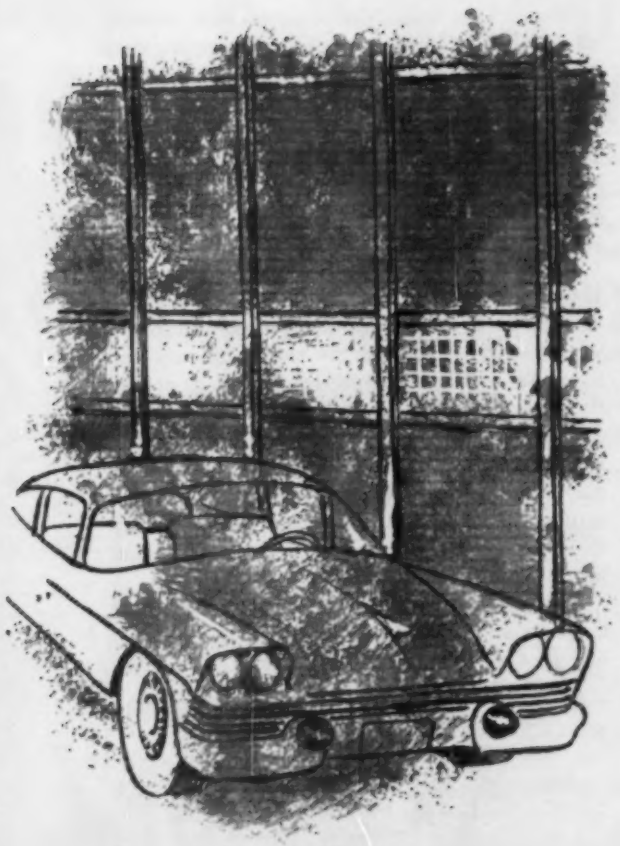
Everywhere one turns the demands are becoming more and more severe. That's why metallurgists are needed badly!



What Is a Metallurgist?

As the name implies, a metallurgist is one who makes the metals useful to mankind. In this sense there have been metallurgists since prehistoric times. With increase in knowledge of physics and chemistry, the modern metallurgist has applied this knowledge to the metals. Today, study of the atoms is one of his chief research functions, for atoms are the fundamental building blocks of the metals. They are assembled in the solid state in precise geometrical arrangements termed crystals. The individual crystals may be very large but ordinary pieces of metal are usually made up of very tiny crystals called grains. In general the smaller the grains the tougher the metal.

Other materials also may be crystalline, such as diamonds and other gemstones. However, the metals have properties not found in the nonmetallic materials, such as the ability to flow under applied load, the ability to conduct electricity, and "metallic luster," the property by which most of us recognize a metal. All of these, and other properties, are governed by the way



the atoms are assembled in the crystals and the forces holding the atoms together. The work of the metallurgist involves getting the different kinds of atoms in the right places to give the best properties. This may be done in the research laboratory on a scale that is microscopic or in the plant with ingots weighing as much as a hundred tons.

Not all the same properties may be required at the same time. For machining in the factories the metal should be fairly soft but should be hardened and strengthened before it goes into service. By proper heating and cooling — "heat treatment" — the metallurgist sees that these requirements are fulfilled for each stage of the manufacturing operation. He must be sure that the proper material is selected which will respond correctly to this heat treatment.

Research and Development

Modern industry has an insatiable appetite for new and better materials of construction. Every large and many of the small producers in industry have laboratories for the development of new materials. Industrial users are fully as much concerned as producers. For example, the annual cost to the chemical industry due to corrosion failure is enormous.

Industries are intensely interested in the fundamental structure of the materials, for here lie the secrets of greater improvement. Tools and instruments for these investigations, although the most modern that have been devised, can scarcely keep pace with the needs of the research metallurgist in his probing ever deeper into atomic structure. Light microscopes, electron microscopes, radioactive isotopes and Geiger counters, X-ray apparatus, cathode-ray oscilloscopes — all these are familiar in every modern laboratory.

The new materials designed through this basic knowledge must be put in the hands of the ultimate user. This is a long road, from the laboratory through trial, production, sales and usage and comes under the general heading of development. Full-scale samples must be placed in the customers' hands for the most exhaustive tests to show that a superior material is being offered. The development metallurgist must follow every stage to eliminate the "bugs" as they appear.

Preparation and Qualifications

Before deciding to enter the field the prospective metallurgist of high-school age should survey himself to see if he has the necessary aptitudes and qualifications. A long course of training is required which does not stop with the acquisition of a college degree.

It begins even before entering college. The basic courses of science and engineering are required in metallurgy — these include algebra, geometry, trigonometry, physics and chemistry. These should be started in high school. The future metallurgist should have curiosity and imagination, especially about material things.

It will take him four years of college to earn a Bachelor of Science degree in metallurgical engineering. Necessary courses here include higher mathematics, physics, chemistry, mechanics and all available courses in metallurgy. For broader background will also be required English, history and economics.

Specific knowledge of particular alloy systems or metallurgical operations is usually required on the job after graduation. However, further study in graduate school is strongly recommended for those qualified. Here one may specialize in some branch of metallurgy and take part in metallurgical research.

Opportunities

Metallurgy is creative. To the individual who has aptitude and curiosity the field is unlimited. Such an individual would never be satisfied in a trade or as a technician.

Our nation has been built on its metalworking industry. Yet only some 600 metallurgists per year are being graduated from our colleges and universities to control 35 *billion* dollars of product! Even in the depths of depression metallurgists are in demand and can find the area for which they are best adapted and which appeals to them most, whether it be research, development, production or sales. If he shows executive capabilities the way is open for him to go to the very top, as many metallurgists have done, particularly in the producing industries.

Salaries

A recent survey of the American Society for Metals showed that the salary offered in the spring of 1958 for graduate metallurgists after a four year course leading to a bachelor's degree ranged from $400 to $450 per month – high for all engineers. Many companies offer a reduced work schedule at no reduction in salary to provide opportunity for advanced work leading to master's and doctor's degrees in metallurgical engineering and metallurgists with these degrees may receive as much as $300 a month more than those with a bachelor's degree.

Because of assignment of administrative duties, it is not easy to say what the income of a metallurgist is a few years out of college. From a recent survey of the American Society for Metals, "metallurgists" and "metallurgical engineers" with 20 years' experience have an average salary of $12,600. In common with all engineers and unlike the other learned professions, average salaries for metallurgists increase up until retirement. Many metallurgists continue in a consulting capacity long after "retirement" age.

Metallurgy in the Future

The future and progress of metallurgy is almost without limit. We are delving into areas beyond the wildest imagination. Submarines that can travel a dozen times around the world without pausing to refuel, earth satellites in ever-increasing number, only a step removed from interplanetary travel. The materials to go into these celestial travellers and new devices for world travel will tax our ingenuity and more. But these are the thrilling adventures for you!

Much closer home, the problems that confront us are without number. Mentioned earlier were the enormous costs of corrosion in chemical plant equipment. Think also of corrosion of automobile bodies and trim, of water piping, of farm equipment. Jet engines for airplanes, locomotives, trucks and pleasure cars must operate at much higher temperatures to be economically successful. Electronic ovens and a host of other conveniences in the household are with us now. Our thinking is already turned to new safety devices on the highway, such as radar controls whereby we can travel the superhighways and completely forget the wheel, arriving at our destination surely and safely.

Every service we can think of will call for new and better metal combinations. Our dreams cannot come true until these new alloys become available. Every man-made thing we see, every man-made thing we use depends upon metallurgy and metallurgists.

Can anyone believe this progress will stop? Can anyone believe we will never need metallurgists – more and more metallurgists?

Foil Clad Laminates in Printed Circuitry

*By D. K. RIDER**

Start with an insulating base, glue on very thin copper foil (free of holes or inclusions), etch away unwanted areas leaving behind conductive paths from point to point. This concept leads to rugged assemblies, mass-produced at minimum cost. (T1c; Cu, 4-56)

To ANYONE not associated with the field of electronics, it must seem paradoxical that many elaborate circuits, which are the very heart of automatic devices, are still fabricated and assembled by techniques which belong to the horse and buggy era. Major discoveries have been made in components – witness the transistor and other semiconductor devices. Great reliability has been built into components by refining the materials, designs, and manufacturing techniques. Whole new circuit designs have been conceived. Yet few indeed are the circuits which are produced by fully automatic techniques. From purely competitive considerations, it becomes incumbent on a designer to take advantage of any concept which will fabricate and assemble reliable circuits at lowest cost. In a national emergency, the cost in manpower would become paramount, since the volume and complexity of needed electronic circuits would defy manufacture by conventional methods.

The question might then be asked, "What is necessary to adapt a circuit design to modern automatic production methods?"

A circuit must first of all have form and rigidity to enable a machine to handle it. It should provide insulated conductors spaced in a reproducible, modular pattern. The probability of wiring errors should be reduced to a minimum. Terminals should be soldered simultaneously in large numbers. Circuit changes should be possible with little disruption of production. The assembly should be rugged and compact. Finally, and probably most important, the product should be highly reliable.

It must be acknowledged that some circuits do not lend themselves economically to automatic processing and assembly. Many will be required in quantities entirely too small to warrant establishing an automatic assembly line. Still others, by virtue of their geometry or the presence of a component not readily adaptable to machine handling, will continue to be hand-assembled. Nonetheless, it is safe to say that both manual and automatic assembly can reap the same benefits when they conform to the above criteria because of their rigidity of form, compactness, and geometric uniformity.

Printed Circuitry – All the above requirements, whether for automatic or hand assembly, can be met by printed circuits. A printed circuit can be defined as a pattern which combines components and wiring in some combination, formed in a predetermined design on one or both surfaces of a common base. A printed circuit may contain printed components (such as inductors, capacitors, or resistors) or it may consist solely of printed wiring which provides point-to-point electrical connections or shielding. From this definition it can be seen that a printed circuit board consists of two basic elements – a conductive material and the insulating base which supports it. A means of anchoring the two together is also implied.

Despite the fact that the idea of applying conductors to an insulating base is at least 30 years old, the concept of printed circuitry remained virtually dormant until the middle 1940's, when

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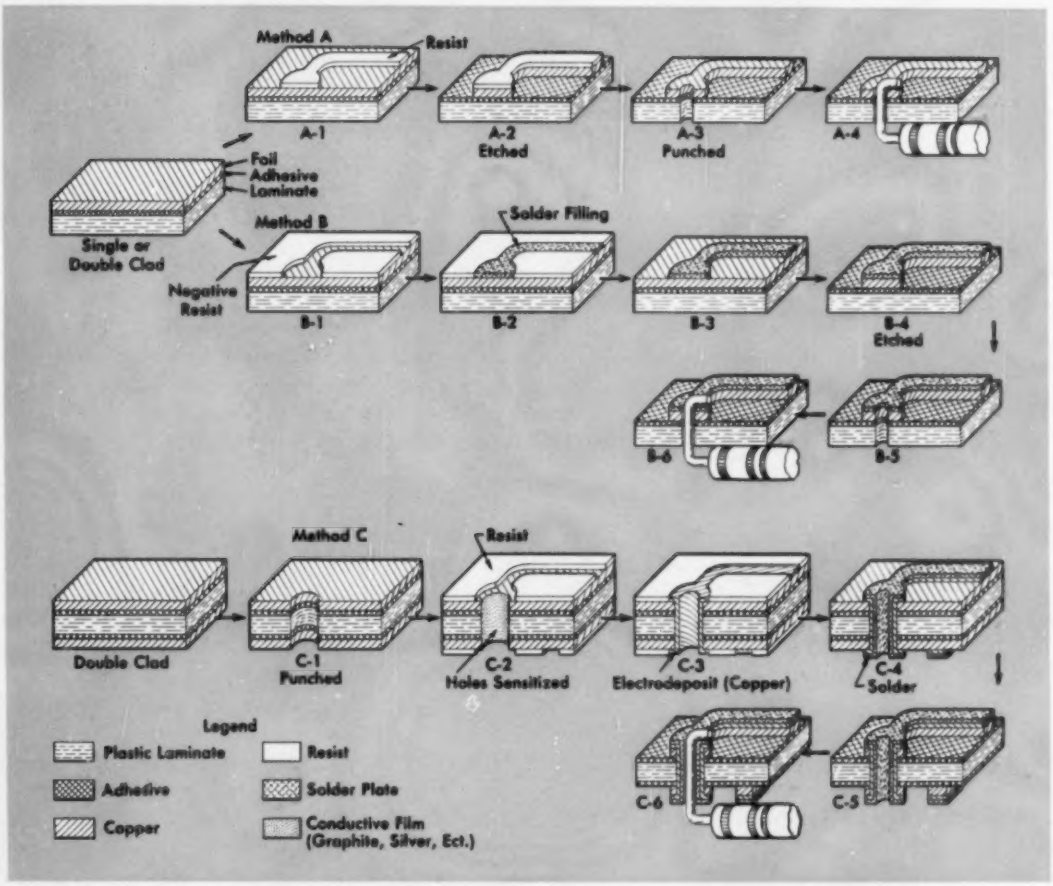


Fig. 1 – Methods of Making Printed Circuits. Method A removes unwanted foil; Method B gives solder-covered conductors; Method C gives "feed-throughs" from one side to the other

it was first used for radio proximity fuses. From that time to the present, the increase in its applications has been phenomenal. Today we find printed circuits in such everyday items as radio and television receivers, hearing aids, telephone equipment, and automobile dashboards, as well as in computers, radar equipment and guided missiles.

Foil Clads – In the manufacture of foil-clad laminates, the foil, coated with a thermosetting adhesive, is bonded to sheets of resin-impregnated fibrous filler, such as paper, fabric or mat. One-ounce or two-ounce electrolytic copper foil (0.00135 or 0.0027 in. thick) is normally used. It is a somewhat refined grade of copper foil of the type long used for flashing by the building trades. It is made in widths up to 60 in. by continuous electrodeposition from a copper sulphate plating bath onto a slowly revolving lead drum. The recent production of rolled copper foil now provides the laminator with a choice of two types of conductors. Aluminum and silver are the only other available foils having sufficient conductivity to be of interest electrically, but the cost of silver and the difficult solderability of aluminum eliminate them from any consideration at present.

Electrolytic foil, as it comes off the plating drum, is sometimes coated with a film of fish oil or wet with a high-boiling petroleum solvent. This minimizes the oxidation of the copper in storage, but it is a surface contaminant which must be removed prior to bonding to the plastic laminate. (Similarly, mill oils must be removed from rolled foil). Some laminators coat the copper with a commercial adhesive or with a material of their own formulation; adhesive manufacturers also manufacture adhesive-coated foil. Each coater, whether laminator or adhesive supplier, has his preferred method for prebond treatment of the copper; for the circuit fabricator the adequacy of the bond lies in its

peel strength and resistance to blister when soldering. Suffice to say that, with properly treated copper, these requirements are met with several types of adhesives.

Etching Processes – Basically, any technique which can apply a conductor pattern to an insulating surface might be termed a printed wiring process. Specifically, foil clad laminates are used in a subtractive process, in which the excess metal is selectively removed to leave the desired conductor paths. One of three basic techniques will generally be employed.

The first to be considered will be the "direct etch process," shown schematically in Fig. 1 as Method A. The resist pattern (A-1) is applied by any one of several methods common in the graphic arts industry. The board is then exposed to an etchant (normally ferric chloride) which dissolves away the exposed copper (A-2). Following a rinse to remove the resist and residual etchant, the board is ready to be punched and trimmed in preparation for the component assembly (A-4).

An alternative method which is sometimes used is shown in Fig. 1, Method B. In this method, a negative or reverse resist pattern is applied (B-1) leaving the desired conductor area exposed. The exposed copper is then covered by approximately 0.001 in. of 60-40 tin-lead solder electrolytically deposited from a fluoroborate bath. The plating resist is then dissolved off (B-3) and the exposed background copper is removed by a chromic acid etchant (B-4), using the electrodeposited solder as the etchant resist. Method B has the advantage of producing a conductor pattern coated with solder, but the greater cost has limited its adoption.

Figure 1, Method C, illustrates a third process which simultaneously provides any number of conductor "feed-throughs" or electrical connections between conductor patterns on opposite sides of the board. Obviously, this begins with a double clad board, which is punched or drilled as a first step (C-1). The hole surfaces are then sensitized with an electrically conductive coating (C-2), either by dipping the board in a suspension of graphite or by silvering. To insure adequate bonding of subsequent electrodeposits, the graphite coating must be removed from the copper surfaces before further processing. A reverse or negative resist pattern is next applied and approximately 0.001 in. of copper is electrodeposited through the holes and onto the exposed copper surfaces (C-3). Over this, 60-40 solder is electrolytically deposited (C-4) and the process then continues in a fashion similar to Method B, where the solder is used as a resist for a chromic acid etchant.

There are serious shortcomings of Method C which tend to outweigh the advantage of simplicity when making numerous "feed-throughs". First of all, once the holes are sensitized, it is almost impossible to clean the copper surfaces sufficiently to insure good adherence of the electrodeposited copper. Furthermore, when the punched board is immersed in the plating bath, the cut edges of the laminate are exposed to ionic contamination. Photomicrographs of sections through the hole areas have shown tentacles of electrodeposited copper extending appreciable distances into the insulator. Concentrations too low to deposit metal, yet more than ample to create severe electrical leakage, undoubtedly extend even farther into the laminate, and may migrate under d-c. potential.

Properties – Printed circuits possess characteristics which differ considerably from conventional wiring. Inasmuch as printed wiring is supported on the surface of the insulator, electrical leakage is far more serious than with point-to-point wiring (where leakage normally can occur only at terminals). Contamination, both in processing and in service, becomes a problem, since residues of etchant and solder flux, fingerprints, and even airborne dirt can induce insulation failures. Another look at Fig. 1 will disclose that one characteristic of all the methods is that a film of adhesive remains on the surface of the boards. The adhesive must therefore be a good insulator as well as a good bonding agent. (There are many fabrication processes for circuits which do not expose the boards to ionic contaminants or leave residues of adhesive between paths, but they do not begin with foil-clad laminates.)

Metal Problem – Doubtless most readers of this article are interested primarily in the problems associated with the metals used in etched foil circuits. The prebond treatment has already been touched on, but another problem, which more properly precedes the bonding, is the uniformity and continuity of the foil. In the not too distant past, commercial copper foil was replete was pinholes, foreign inclusions, and hairline cracks. Adhesive would flow through these pinholes and bond adjacent laminates together in the pressing operation. When separated, the foil surfaces would carry spots of unwanted "resist" next to impossible to remove. In fineline circuits, "opens" frequently resulted from the poor continuity of conductor paths caused by pinholes and cracks in the original foil. The

inclusions caused spotty etching and poorly defined circuits. With subsequent steps taken to refine the foil for electrical use, the difficulties have diminished in frequency, but are still a source of trouble to laminators and fabricators. At this writing, too little experience has been gained with the *rolled* foil to permit speculation as to its over-all quality.

Quite apart from the prebond treating, the physical characteristics of the foil also affect the bond strength. The thicker foils have higher peel strengths than the thin foils, due to the more gradual bend of the metal at the line of separation. A thin 1-oz. foil will bend sharply, thus concentrating the unit stresses on the glueline at the point of failure, with the result that the peel strength may be 20% lower than for a 2-oz. foil. Conversely, a stiffer material, such as the rolled foil, may be expected to yield higher peel strengths than an electrolytic foil of equal thickness, provided adequate prebond treatments are employed. Additive platings and solder coatings may also increase peel strengths, unless the heat of soldering or the chemicals of the plating bath degrade the adhesive joint. A notorious offender is the conventional gold cyanide plating bath which will attack most gluelines, and may even completely lift narrow conductors.

Attachment of component leads by a mass dipping or by fountain soldering is potentially a source of major economies in assembling circuits, yet several factors combine to make soldering a constantly recurring production problem. The limited heat resistance of the organic base and adhesive require soldering at the very minimum temperature. Frequently, 10-sec. immersion at 450° F. is used with a tin-lead eutectic solder. It is unwise to use activated fluxes because of the dual hazards of corrosion of conductors and contamination of the insulating base. The surfaces of the printed conductors and the component leads must therefore be sufficiently receptive to the solder to produce reliable connections under marginal conditions. This frequently means that protective finishes – such as immersion gold flash, hot solder tinning, water dip lacquers – must be applied shortly after the etching step to insure solderability during assembly operations which may occur minutes or months later. Even with such precautions, careful inspection of the soldered connections is a necessity.

Typical Applications – Figures 2 and 3 illustrate the conversion of a conventional point-to-point wired circuit to printed circuitry. Several of the terminal strips (Fig. 2, left) act as the supports for components interconnected by conventional point-to-point wiring. The complexity of the wiring in the assembly of this missile network (Fig. 2, right) resulted in many wiring errors and failures in service, as well as adding materially to the manufacturing cost.

Replacement of the multiplicity of terminal strips and the bulk of the point-to-point wiring with a single printed wiring board, shown in Fig. 3 at top, cut the component assembly time to approximately one quarter what it had been

Fig. 2–Some of the Terminal Strips (Left) and Final Assembly (Right) of Missile Network by Conventional Point-to-Point Wiring

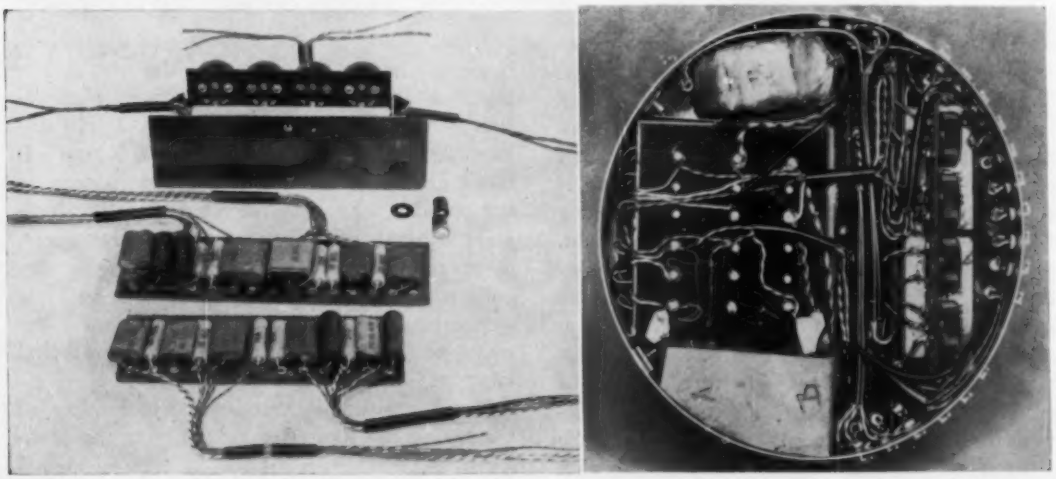
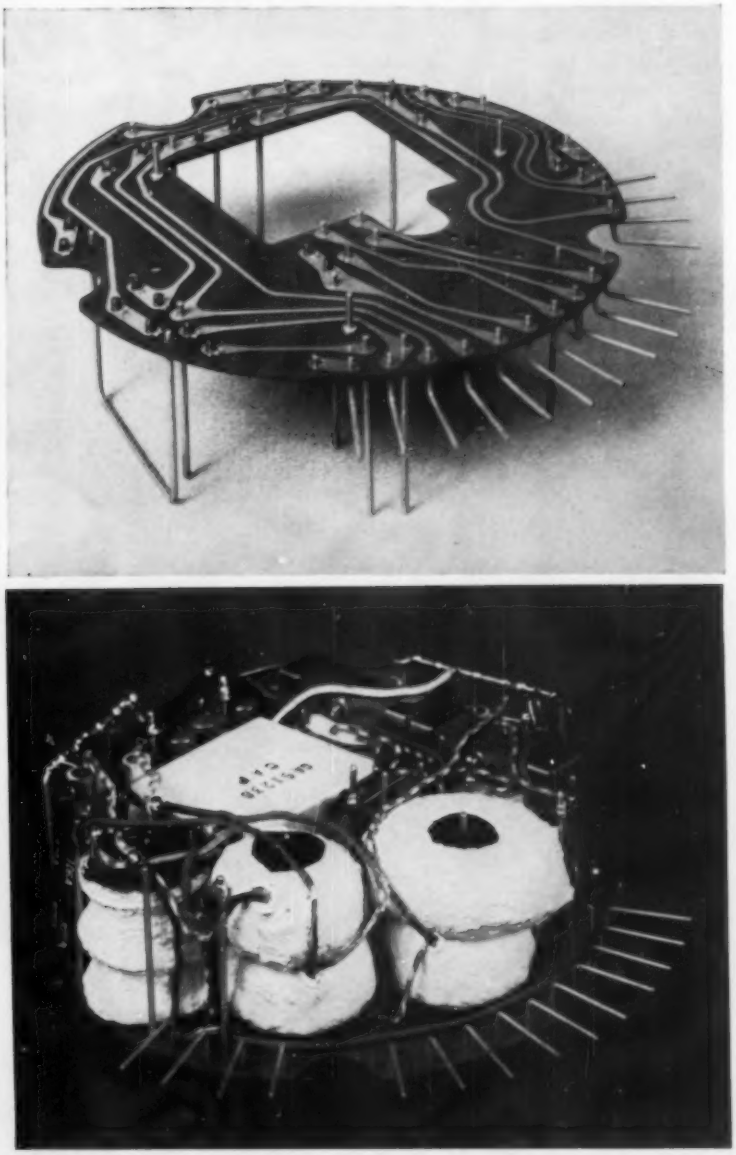


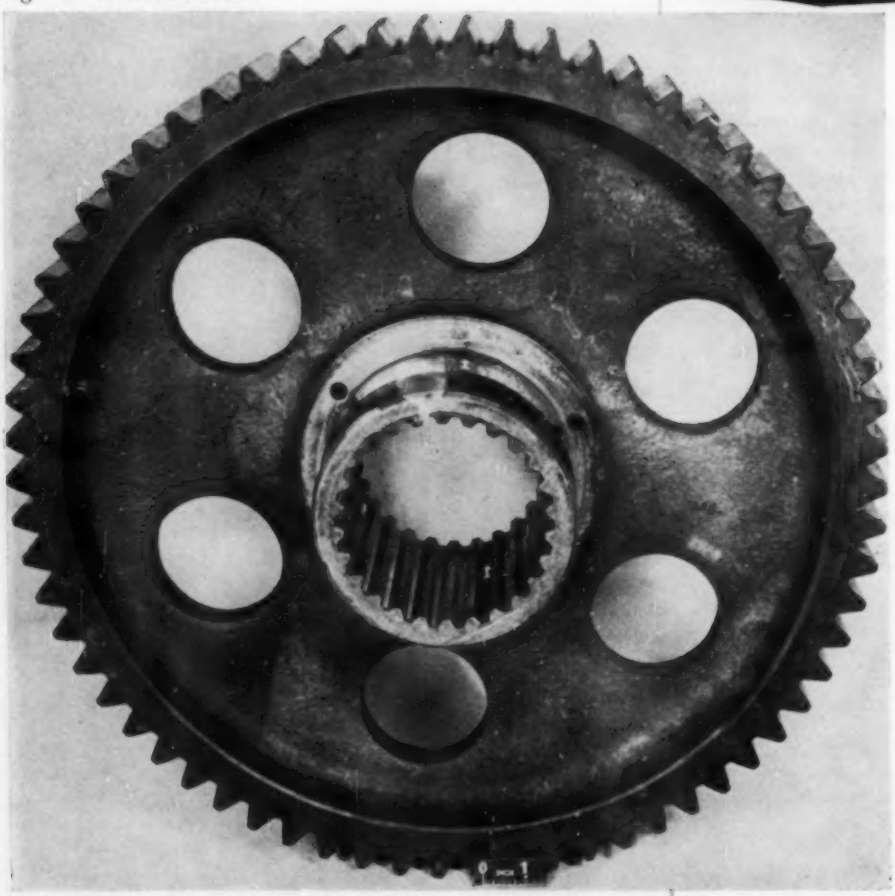
Fig. 3 – Printed Circuits (Top) and Final Assembly (Bottom) of Same Missile Network Before Encapsulation



previously. The resulting assembly (Fig. 3, below) was more economical to manufacture, inspect, and repair, and infinitely more reliable in service. Some point-to-point wiring was still necessary in this particular circuit, to facilitate the flow of an encapsulating resin around the circuit elements in a subsequent stage of manufacture. This was a minor problem.

Future Role – Regardless of the future direction taken in electronic circuit design, one can be certain that printed circuits will play an ever-increasing role. Trends may develop away from the etched foil processes described in this article. It seems probable, however, that the etching of copper foil-clad laminates – because of the simplicity and adaptability to change – cannot fail to occupy an important position, particularly in the development stages of circuit design, and in the manufacture of items of limited demand. With coming improvements in raw materials and in processing techniques, as well as in increased understanding of such things as contamination of insulators, thermal degradation, solderability, and effect of environments on the electrical leakage, there is no reason why the use should not continue to grow.

Fig. 1 – Final Drive Gear



Case History on Induction Hardening Large Drive Gear

*By VICTOR H. PAGANO and CHARLES J. KROPF**

Changing from carburizing to induction hardening permitted the use of less costly steels, and saved 5 lb. of nickel and 0.3 lb. of molybdenum per gear. Heat treating time was decreased, material handling was simplified, and it is claimed that the change resulted in a tenfold increase without sacrificing quality. (J2g, T7a; ST)

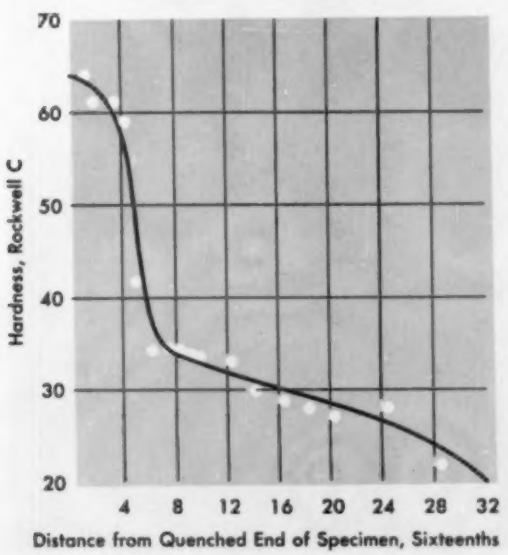
THE FINAL DRIVE GEAR shown in Fig. 1 transfers torque from the transmission to the track sprocket of the M47 and M48 tanks. Originally the gear was carburized to a case hardness of Rockwell C-58 to 62. The idea of switching to induction hardening was considered and eventually adopted. Here localized hardening provides strength and wear characteristics needed, without using highly alloyed steels. Also, material handling is simplified and production rate is increased.

The drive gear is a rim-web-hub design, 19.44 in. OD, 3¼ in. face width, and 19 in. pitch diameter. The 76 teeth, of involute design, have a chordal thickness of 7/16 in. Case depth required was 0.060 to 0.080 in.; core hardness at the pitch line, center of tooth, was C-25 to 35. These requirements are inevitable in military vehicles designed with minimum space and weight and maximum performance in mind. Because of the extreme stresses, low-carbon, heat treatable alloy steels containing 3.25 to 3.75% Ni (A.I.S.E. 4812 and 4815) were selected.

This article lists the steps taken in the appraisal of a new technique, and also includes the production procedures eventually adopted.

Induction hardened gears used a boron steel, A.I.S.I. TS 14 B 50, containing 0.57% C, 0.83 Mn, 0.24 Si, 0.007 B, and residual elements. Jominy hardenability is shown in Fig. 2. This material met the physical requirements – gear teeth core and surface hardness – needed for satisfactory performance. Some reduction in surface hardness was conceded since it was felt that running speeds did not require adherence to the higher hardness levels achieved through carburizing.

Fig. 2 – Jominy Hardenability Curve of A.I.S.I. TS 14 B 50 Steel



At this point, the shop operations and common difficulties (machining and heat treatment) encountered in the manufacture of the carburized gear will be reviewed, as a reference basis.

First, the forged gear blanks were normalized, then rough machined. This operation included rough cutting the gear teeth. In order to obtain maximum dimensional stability in the finished product, a stress-relieving heat treatment at 1000° F. for 2 hr. was conducted. Finish machining was then carried out on the rim, hub, and gear teeth prior to inspection, masking, carburizing and hardening operations.

Carbon potential during carburizing and hardening was maintained at 0.7 to 0.9% carbon. After carburizing and hardening (about 12 hr. at 1650° F., followed by an oil-die quench), the gear was given a low-temperature stress-relief at approximately 300° F. and then re-inspected dimensionally. Any error in run-out and parallelism was compensated for by broaching the hub internal spline in reference to the teeth of the gear. The unorthodox broaching technique was necessary in order to establish dimensional accuracy since no machining on gear teeth is allowed after the hardening operation. Balancing the gear, shot-peening and copper plating of gear teeth completed the manufacturing operation.

Case hardness of the finished gear was C-58 to 62; effective case depth 0.060 to 0.080 in.; and the core hardness was C-25 to 35.

With this background and a knowledge of induction hardening experience of the tractor industry (see "Case Hardening Large Gears With High-Frequency Current", by G. C. Riegel, *Metal Progress*, July 1943, p. 78), metallurgical and processing requirements for an induction hardened gear were tentatively established: The teeth should have a minimum hardness at pitch line of C-55, and a minimum hardness at root circle of C-50, with a minimum 0.050 in. below and under the root of C-50; the core hardness should be C-25 to 35.

Processing was set up to follow essentially

*Materials Engineers, Industrial and Research Development Divisions, respectively, Ordnance Tank-Automotive Command, Detroit Arsenal, Center Line, Michigan. Thanks are due to the International Harvester Co., and John Deere Tractor Co., for information on tractor gear hardening techniques and processing methods. Opinions expressed are those of the authors and should not necessarily be construed as official or reflecting the views of the Department of the Army.

the same operation as for the carburized gear. Normalizing would be followed by rough machining, except that the hub would also be bored. The gear would then be stress-relieved as before but would also receive an oil-die quench and tempering operation (tempered hardness being controlled by the core hardness requirement of C-25 to 35).

Internal splines would then be broached, followed by finish contouring of the gear teeth (from a spline reference this time).

Following machining operations, the gears would be checked dimensionally, preheated, induction heated, and hardened on the teeth only, tempered, rechecked dimensionally (growth characteristics), and then balanced, shot-peened, and copper plated.

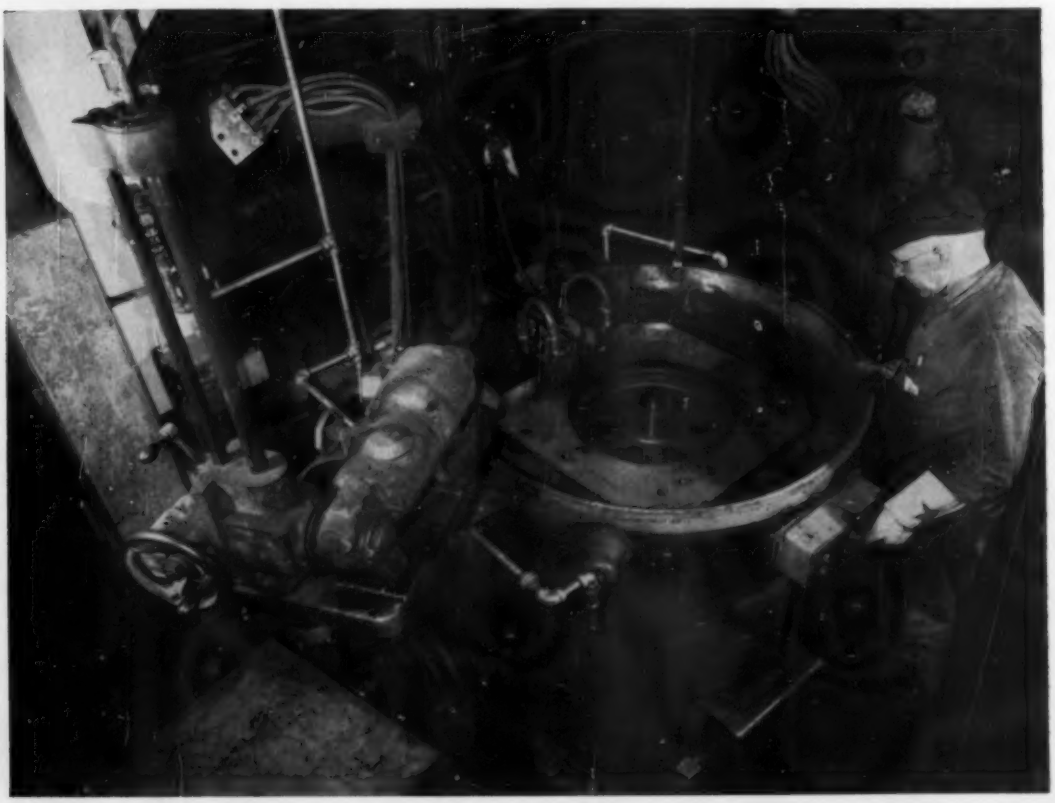
At this point in the study it seemed obvious that handling and heat treating time would be decreased, and appreciable alloy savings would result.

With this as a background, 12 gear blanks of A.I.S.I. Type 14 B 50 steel were processed up to the finish machining operation. Eight gears were finished to a predetermined shave size on the teeth based on an estimate of anticipated growth. The remaining four were held pending a dimensional analysis after induction hardening.

For the induction hardening phase of the program, a manufacturing source was sought having electrical equipment capable of producing a heating cycle for contour hardening, and a contract was awarded to Westinghouse Electric Corp., Pittsburgh. The two-station motor-generator set, rated at 700 kw., 800 v., 9600 cycles, per sec., available at the Westinghouse plant, was considered ideal for the development work contemplated. Preliminary work in this phase involved the design of an induction coil and a spray-quench ring.

After several trials, a 4-turn inductor coil (20 in. ID) capable of producing the desired energy input was developed. The coil consisted of 4 turns of ¾-in. square copper tubing, with the turns spaced ¼ in. apart. In addition, an oil-spray brass-faced quench ring (20 in. ID and 4 in. high) was designed and tested. The per-

Fig. 3 — View of Induction Hardening Station Showing Tank Gear in Position. (Courtesy Westinghouse Electric Corp.)



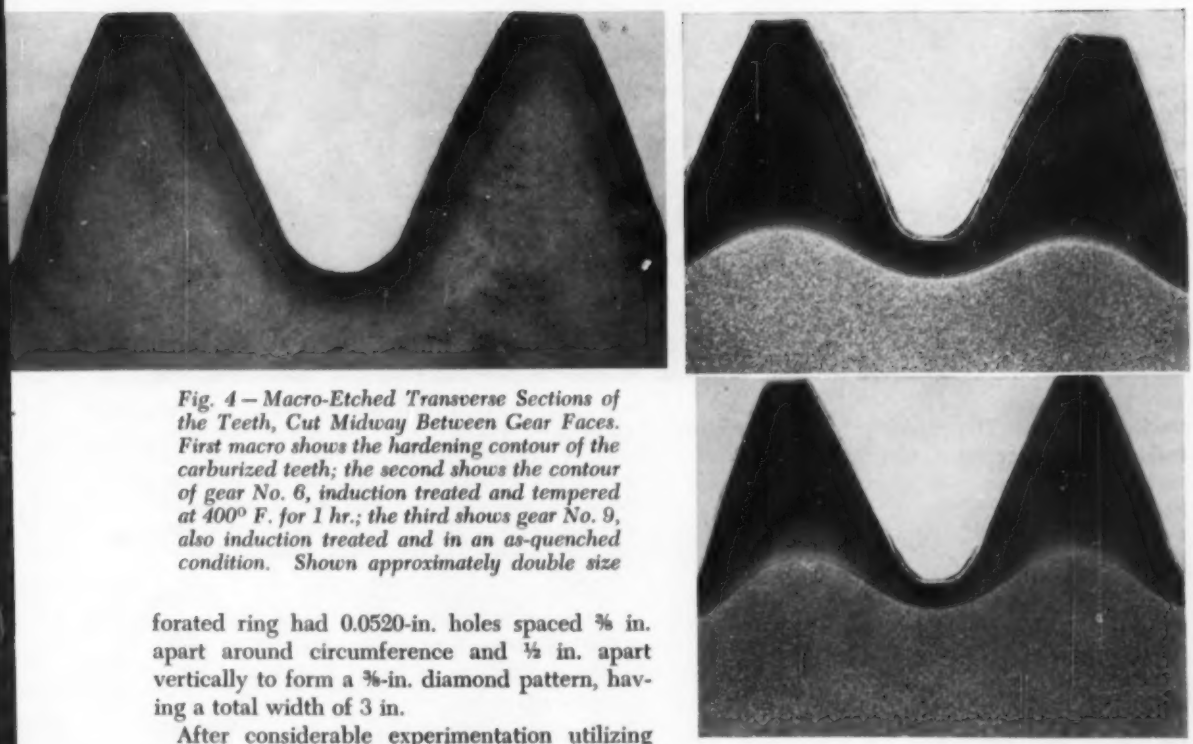


Fig. 4 – Macro-Etched Transverse Sections of the Teeth, Cut Midway Between Gear Faces. First macro shows the hardening contour of the carburized teeth; the second shows the contour of gear No. 6, induction treated and tempered at 400° F. for 1 hr.; the third shows gear No. 9, also induction treated and in an as-quenched condition. Shown approximately double size

forated ring had 0.0520-in. holes spaced ⅜ in. apart around circumference and ½ in. apart vertically to form a ⅜-in. diamond pattern, having a total width of 3 in.

After considerable experimentation utilizing nine of the gears, an acceptable contour hardening cycle was established, based on the following sequence.

1. Place the preheated (700° F.), completely machined gear on the hydraulic ram-supported mounting fixture.
2. Set the gear in motion (23 rpm.) by means of a rotating mechanism.
3. Energize the coil with high-frequency power. After the gear teeth reach austenitizing temperature, the inductor coil is automatically switched off.
4. The heated gear is submerged, still rotating, into the oil-spray quench bath to harden the gear teeth (oil pressure 52 psi.).
5. Spray quench is turned off, gear is raised to starting position and rotation is stopped.
6. Rotating mechanism is disengaged; gear is removed and set aside for the tempering operation (1 hr. at 400° F.).

Total elapsed time from heat initiation through the quench cycle was 73 sec. – 11 sec. heating (power peak of 650 kw.), 2 sec. delay, 60 sec. quench. Figure 4 compares hardening contours of macro-etched sections of carburized and induction hardened teeth. Typical tempered microstructures of the induction hardened zones and unaffected base material for all the gears induction treated are shown in Fig. 5.

Because of the great mass of the gear blank and shallow hardening nature of the steel, there was some doubt whether the hub spline area could be hardened by oil-die quenching to meet the minimum specified core hardness. A hardness traverse at the hub spline root showed a variation from C-31 to 15, but this was found to be adequate to withstand service loads.

Tempered hardness of the gear teeth at the pitch line was C-57, and the hardness of the partially hardened core ranged from C-25 to 57, well within initial estimated requirements.

From the original 12 test gears, four were set aside for vehicle test. One of these (gear No. 7) possessed the first hardening pattern, and the other three gears (No. 10, 11 and 12) represented the hardening cycle finally established.

Now that finished gears were available the next question was "Would they provide satisfactory life service?" This was answered by a series of sustained vehicle tests under various environmental and road conditions.

The first gear tested (No. 7) underwent a mileage equivalent to 125% of expected service life, being inspected and compared at 500-mile intervals to a carburized running mate installed on the opposite side of the vehicle. Test track mileage consisted of 40% infield and 60% dirt

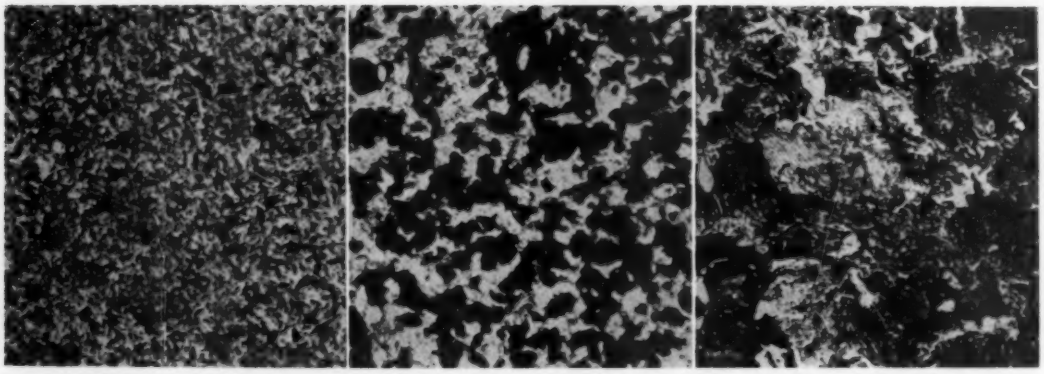


Fig. 5 – Microstructures of Induction Treated Gear No. 9. The first micro shows a typical tempered martensitic structure in the fully hardened zone. The second micro, taken from the partially hardened zone, shows a structure of martensite and fine pearlite. The third shows unaffected rim material composed of ferrite and pearlite. 500 ×

track operation. The vehicle was subjected to sudden full-power turns, pivot steering and reverse gear operation in order to supply maximum loading.

Visual inspection of the gears at 500-mile intervals and Magnaflux inspections at 37½% service life and at 125% service life showed no indication of impending failure. Wear on the induction hardened gear was less than that on the carburized gear. Furthermore, wear on the carburized pinion mated to the induction hardened gear was considerably less than that on the pinion mating with the carburized gear.

The next gear evaluated (No. 10) was installed on a vehicle undergoing hardship tests at subzero temperature at Fort Churchill, Manitoba, Canada. During this test, the gears were subjected to frequent impact load conditions to evaluate brittle behavior. Satisfactory performance under the above conditions was experienced after a mileage equivalent of 142% of expected service life. At the same time that gear No. 10 was being tested at low temperature, gears No. 11 and 12 were sent to Aberdeen Proving Ground, Aberdeen, Md., for special operational tests. After accumulating a mileage equal to expected service life, on paved, gravel, cross-country, and hill cross-country terrain, the gears showed no appreciable sign of wear. The gears were also subjected to approximately 1100 pivot turns of the vehicle. One gear also survived the failure of its mating carburized pinion during testing. The failure was traced to uneven load distribution resulting from bull gear misalignment attributed to a loose spline fit between the output shaft and gear. After test, Magnaflux inspection showed no flaws.

With this background, another investigation was authorized, that of the manufacture of induction hardened gears from A.I.S.I. 1057 steel for field testing in M 48 vehicles. Use of A.I.S.I. 1057 steel was considered at this time because of the greater availability over TS 14 B 50 grade. Preliminary results indicate that this steel is similarly adaptable.

It is appropriate at this point to analyze the results and establish the success factors. The foremost factor was the excellent dimensional stability or minimum distortion produced after hardening. This stability is clearly a function of the hardening method. With induction hardening the number of distortion variables encountered is minimized as compared to the carburizing method. In the carburizing process, for example, the entire gear is at the hardening temperature and, on quenching, unbalanced thermal stresses are created proportional to the mass and geometry of the gear. In addition, the difference in carbon level between the case and core alter the critical temperatures enough to create nonuniform transformations within the gear teeth, contributing to the formation of a more unpredictable residual stress state. Both of these sources of variable stresses are avoided by induction hardening, because of the small mass of metal heated and the lack of two distinct transformations on quenching. The distinct contour hardening and single transformation is more predictable and more desirable.

Specifically, induction hardening has resulted in a tenfold increase in production rate over the previous method, and by substituting less costly materials, a total cost saving of $20 per gear has been attained. Perhaps equally important, the service life of the gear has been improved.

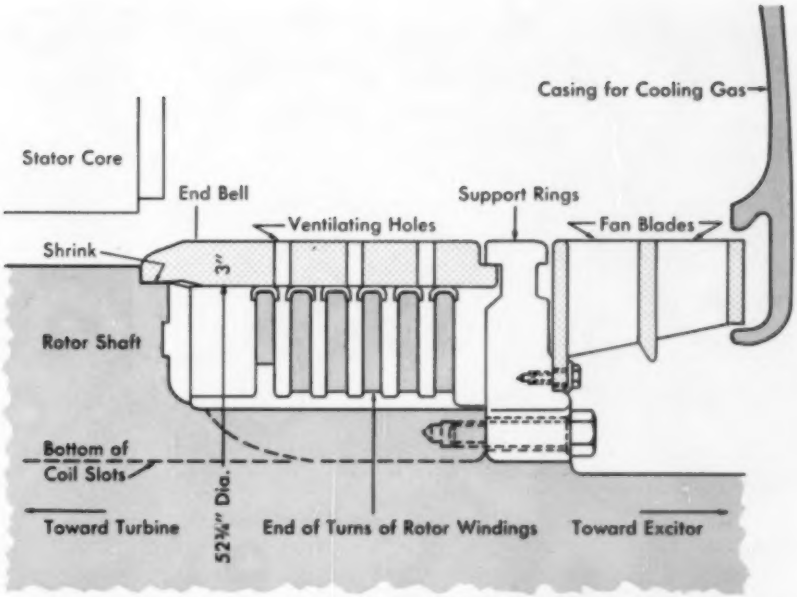


Fig. 1 – Cross Section at End of a Rotor Shaft, Showing Function of Retaining Ring (Here Called "End Bell") to Hold Return Loops or End Turns of the Rotor Windings. Reproduced from Metal Progress, *July 1956*

Another Turbogenerator Failure

*By R. JAMES LANDRUM**

Another failure in a turbogenerator, similar to the accidents in Toronto described in *Metal Progress* for July 1956, was due to the presence of fatigue cracks at ventilating holes. These acted as stress-raisers during temporary and minor overspeeding, inducing an almost instantaneous brittle failure which wrecked the machine – fortunately without human casualty. (Q26s, Q7, W11q, 17-51; AY)

In 1955 Sir Claude Gibb of C. A. Parsons & Co., the British engineering firm, presented a paper to the Institution of Mechanical Engineers discussing the failures of two 100,000-kw. electric generators. An eight-page summary of this paper and the discussion was printed in *Metal Progress* in July 1956. Two of three units, built by his firm and installed in Toronto, had failed when the forged austenitic steel rings at the ends of the rotor shafts had burst. Sir Claude's presentation was concluded by stating, "In matters of such widespread importance as the Toronto failures, it is clearly the duty of all concerned to sift the evidence carefully and to publicize the results of every practicable investigation as to the cause."

*Group Supervisor, Applied Engineering Materials, Engineering Service Div., Engineering Dept., E. I. du Pont de Nemours & Co., Wilmington, Del.

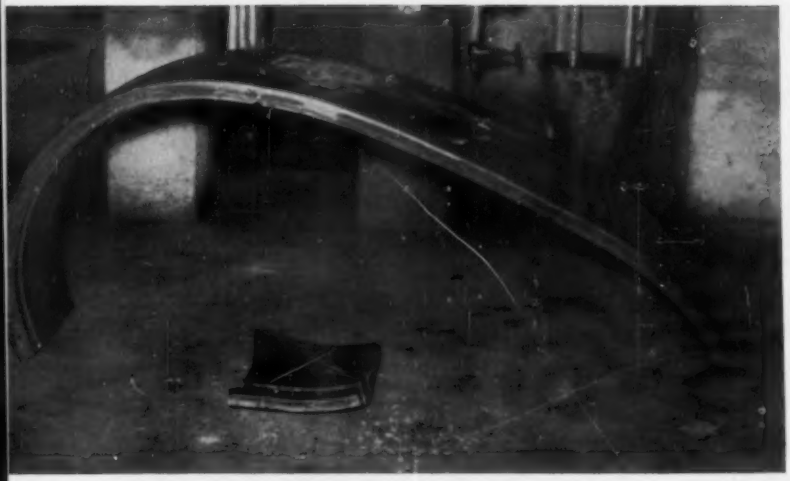


Fig. 2 — Fractured End Ring, the Large Piece Partly Straightened Out During the Catastrophe

Fig. 3 — Photograph of Fractured Surface. Note indistinct chevron markings in midsection, pointing upward. Dimensions: 1¼ in. thick, 1⅝ in. high

Recently, a 3000-kw. turbogenerator failed during operation at our plant in Old Hickory, Tenn. The marked similarity to the Toronto failures prompted the writing of this article.

The generator was installed in 1934 and had served continuously since that time. On the day of the failure, the unit was operating normally at full load and 3600 rpm. Suddenly the unit overspeeded due to loss of field and then the turbine tripped out. The steam throttle was immediately closed by the operator and the turbine slowed down to where the overspeed trip could be relatched — a speed estimated by the operator as about 1000 rpm. The throttle was then gradually opened by the operator to bring the unit up to speed before putting it back on the line. He estimated that the machine had reached a speed of 1800 to 2500 rpm. when fire flashed at both ends of the generator. Seconds later the machine wrecked itself. Parts were scattered over the powerhouse, some going through the roof. Even though fragments of the shattered machine were scattered over a wide area, fortunately only one slight personal injury occurred.

Immediately, an engineering investigation was started to establish the cause of failure. From metallurgical evidence it was concluded that damage originated in the rupture of a retaining ring at the outboard end of the generator. There are two such rings, one at each end of the generator. These rings hold the return loops of the windings in place as shown in Fig. 1. These retaining rings, referred to as "end bells" in England and Canada (and in the sketch, Fig. 1), are often made of a nonmagnetic alloy to minimize eddy currents and heating therefrom, thus improving the efficiency of the generator. After the accident the inboard field retaining ring

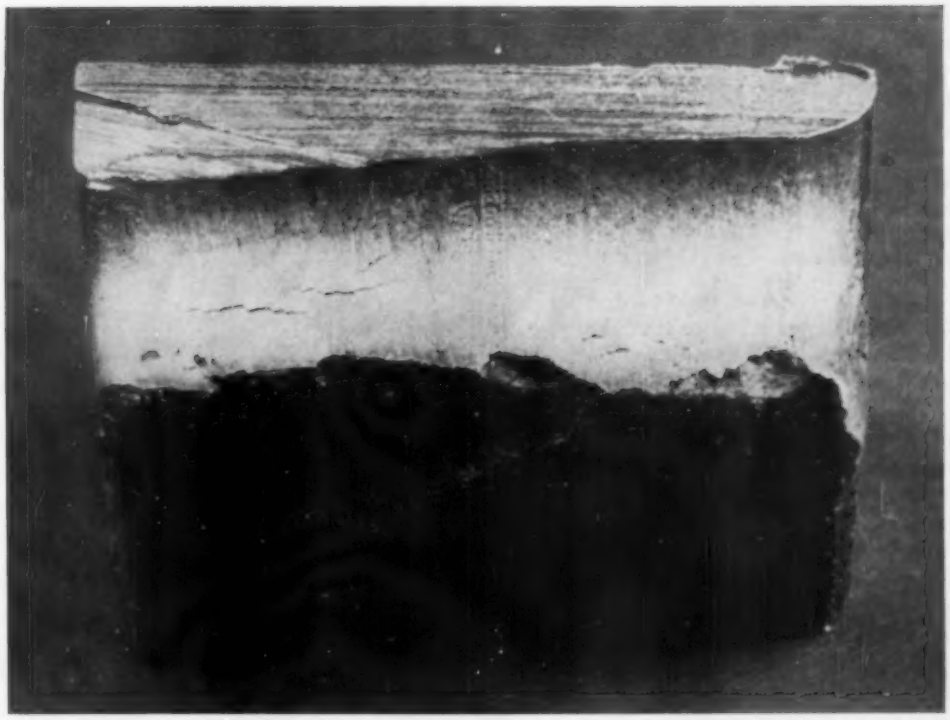


Fig. 4 – Inner Surface of Mating Portion of Top Air Hole in Fig. 3, Showing Cracks. Magnification 2.5 ×

was found securely in place on the rotor but the right end ring was missing. It was found in two pieces in the pit under the generator after the accident. The large piece was partly straightened out as shown in Fig. 2. Original dimensions of the ring were: inner diameter 24 in., thickness about 1 ¼ in., length 1 ⅝ in., weight 325 lb.

The broken parts of the outboard retaining ring were carefully examined by the naked eye and by microscope. Figure 3 shows one of the original fracture surfaces. There was little evidence of plastic deformation. This indicates a brittle break, a conclusion substantiated by a chevron pattern (only indistinctly shown in the lower part of the photograph), indicating that a crack had started at the top air hole as shown in Fig. 3 and had progressed in both directions. One direction led from the originating hole a short way to the outside of the ring. In the opposite direction, the crack propagated to the second air hole and thence to the other edge of the retaining ring. The apexes of the herringbone markings point to the start of the crack showing this progression through the ring.

The entire surface of the ruptured retaining ring was cleaned of all heavy tar and carefully examined; cracks were found on the inner surface of another air hole. These cracks appeared at two diametrically opposite sides of the hole and followed a direction perpendicular to the principal applied stresses. The inboard retaining ring which had not broken was also examined and the same kind of cracks were found in several air holes.

The mating piece of that shown in Fig. 3 is shown in Fig. 4. Cracks are visible similar to the crack of the original fracture at the lower edge. Figure 5 shows photomicrographs of cracks located near the area originating the failure, taken normal and transverse to the axis of the air hole.

Chemical analysis showed the retaining ring to be a high-carbon, nickel-manganese-chromium steel of the following composition: 0.74% C, 9.94% Mn, 3.54% Cr, 5.05% Ni, 0.38% Mo, 0.54% Cu, 0.012% Ti, nil Cb, 0.025% P and 0.009% S.

The composition of the English "end bells" was also a high-carbon, nickel-manganese-chromium steel but the manganese was about 1.5% lower and the nickel about 3.5% higher than the above composition. At the normal 3600-rpm. operating speed, the retaining ring had a hoop stress of

26,500 psi. A series of tensile tests was made on specimens cut parallel to and transverse to the axis of rotation of the retaining ring with the following average results:

	Longitudinal	Transverse	
Ultimate strength	125,425	130,000	psi.
Yield (0.2% offiset)	74,450	79,350	
Elongation in 2 in.	9.5%	12.8%	
Reduction of area	9.8	13.8	

Summary – It was concluded from the metallurgical evidence that, during the 23 years of operation of the turbogenerator, the austenitic stainless steel rings were being subjected to cycles of repeated stress which in turn produced intercrystalline slip and, in time, small cracks were formed in the inner surfaces of the air holes. (This opinion is borne out by the fact that cracks were found in air holes of the retaining ring that had not failed.)

On the day of the failure, when the electrical load was lost and the rotating field oversped, the ring was subjected to a much higher stress than normal. It was calculated that during this period of overspeeding the stress in the retaining ring was about 35,000 psi. This is considerably lower than the yield strength determined by test; however, the air holes undoubtedly acted as stress-raisers leading to a stress-concentration factor of about three. The yield strength of the material, therefore, was exceeded. This overstress caused the cracks in the air hole to propagate at a fast rate. The rotor was then slowed down, going through the "critical speed" of about 2460 rpm. at which speed the increased vibration further accelerated the rate of crack propagation. It was not until the generator was again speeded up to the critical speed of the shaft, resulting again in excessive vibration, that the final rupture occurred.

When the retaining ring broke, it opened up and a leading edge rubbed against the stator coil ends tearing insulation and copper and causing the observed fire at both ends of the generator. The ring opened up further and finally gouged into the stator so deeply that the ring and rotor suddenly stopped after about three quarters of the end windings had been cut.

We concluded that the failure would not have occurred if there had been no ventilation holes.

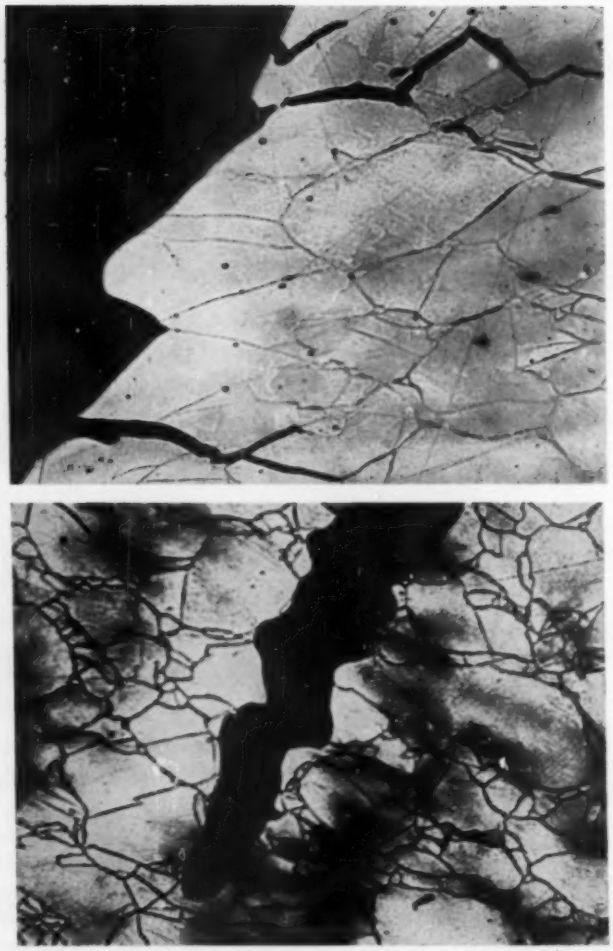


Fig. 5 – Cross Sections Through Cracks, Respectively Normal and Transverse to the Axis of the Air Hole. Etched in 2% nital; magnification 100 ×

This conclusion concurs with the findings of the investigation of the Toronto failures.

Two problems have to be faced: (*a*) What should be done about other turbogenerators with austenitic retaining rings which are in service; (*b*) what should be done about replacing retaining rings of old units and specifying retaining rings for new turbogenerators? The first problem is being answered by carefully inspecting retaining rings for cracks during regular maintenance work or when periodic inspections are scheduled. Since incipient cracks are not always easily visible to the eye, a dye penetrant is being used. When cracks are found, the retaining ring is replaced. The second problem is being answered, where practical, by using retaining rings with no ventilation holes.

Powder Metallurgy of Refractory Metals

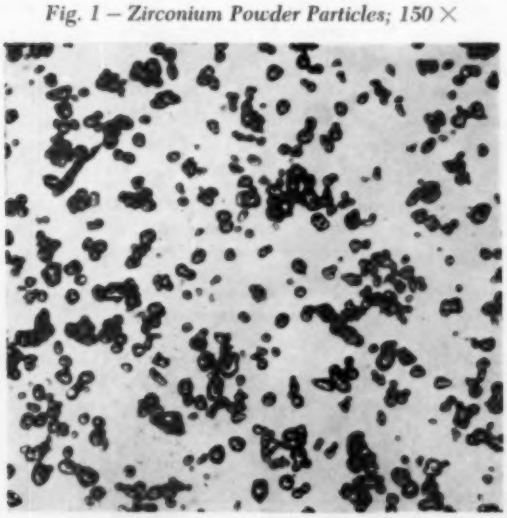
*By ALAN BLAINEY**

Hydrostatic compaction, extrusion of canned powders, and compression within deformable frames are interesting techniques utilized for cladding fuel elements with pure refractory metals and making special shapes for atomic power reactors. (H-general, T11g; Zr, Cb, V, Be, Mg)

AN ARTICLE entitled "Powder Metallurgy of Uranium and Thorium" appeared in *Metal Progress* last month, the first of a series intending to give a broad view of recent progress in the powder metallurgical art in Great Britain. Since much of this progress has had to do with the utilization of the refractory and chemically active metals, this installment will carry the consideration into work on cladding metals for nuclear fuel elements.

In this relationship, the metals zirconium, columbium, vanadium and beryllium may be considered. Zirconium has applications in water cooled and moderated thermal reactors, especially the types which have been so successful as power plants in American submarines. Columbium has very good physical properties at high temperatures and also has a reasonably low absorption coefficient for thermal or slow neutrons. It might be used in thermal or fast reactors. Vanadium is promising for fast reactors. Beryllium, owing to its low absorption cross section for thermal neutrons, its high melting point, low solid solubility of most other metals (in particular uranium) and good resistance to attack by gaseous and some liquid metal coolants, is an excellent fuel cladding material for moderately high-temperature thermal reactors. The plutonium producing piles at Richland, Wash., use aluminum for cladding the uranium slugs and protecting them from corrosion by the coolant (water at river temperatures). The fuel slugs in the power producing British reactors – operating at much higher temperatures, around 700° F. – are clad in a magnesium alloy† and the coolant is CO_2 gas. These two light metals, aluminum and magnesium, are handled in conventional mill operations and (except for one modification) will not be discussed in this article.

Fig. 1 – Zirconium Powder Particles; 150 ×



Zirconium

Sintering of zirconium powder was studied by Chuang at Liverpool University. Powder, supplied by Murex Ltd., was prepared by magne-

*Adamant Research Laboratory, Anglo-American Corp., Johannesburg, Union of South Africa; Sometime Powder Metallurgist, U.K. Atomic Energy Research Establishment, Harwell, England.

† See *Metal Progress*, June 1957, p. 68.

sium reduction of zirconim tetrachloride at a temperature not greater than 900° C. (1650° F.), then leached of magnesium chloride and excess magnesium. About 1% Mg remains in the zirconium powder but is evaporated during sintering – or it may be largely removed by heating to about 850° C. (1560° F.) in vacuo if the powder is required for hot compacting. The appearance of the powder particles is shown in Fig. 1.

Chuang found that such powder could be readily compacted to a high density at a pressure of 54 tons per sq.in., and sintering these compacts at 1300° C. (2375° F.) in high vacuum produced material whose density was 6.2 g. per cc. and whose hardness was Rockwell B-94. It could be rolled to 50% reduction without cracks occurring.

The powder was also used to prepare numerous alloys by sintering, to study the dispersion of uranium particles in a zirconium matrix by hot compacting, and to produce protective coatings of zirconium alloys.

These protective coatings, which were applied to Nimonic alloys (hardenable Ni-Cr alloys), were formed *in situ* by coating the article with a thin layer of zirconium powder or powder mixture followed by heating in a high vacuum to the range of 970 to 1170° C. (1775 to 2140° F.). Such coatings are resistant to attack by gamma uranium; a typical application of such zirconium coatings is to protect dies used for hot extrusion of uranium.

Preliminary work on high-temperature brazing of Nimonic alloy strips by zirconium alloy interlayers formed in this manner showed that if the brazing layer was less than 0.003 in. thick, the joints possessed shear strengths of up to 27,000 psi. at a test temperature of 1050° C. (1925° F.) and 13,500 psi. at 1150° C. (2100° F.). When the brazing layer was made very thin, it was largely absorbed into the body of the metal, resulting in an autogenous weld containing small isolated inclusions.

Columbium

The metallic powder may be produced by two methods: (*a*) the interaction of the oxide and carbide at high temperature in high vacuum and (*b*) hydrogen reduction of $CbCl_5$. The former method is used commercially and requires a supply of pure oxide (in particular, free from tantalum). The latter method (which has been explored and developed by the Culcheth Laboratories of the U.K. Atomic Energy Authority)

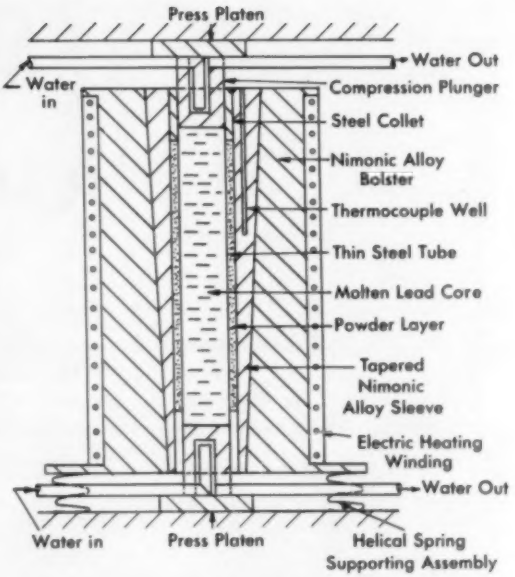


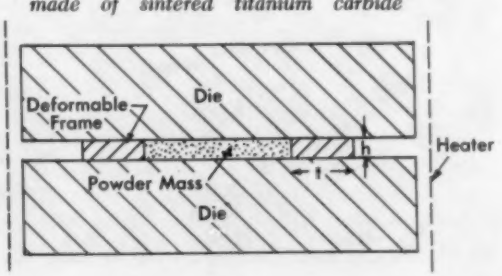
Fig. 2 – Assembly for Hot Compaction of Tubular Shape by Hydrostatic Internal Pressure

has the merit of separating the columbium from most of the contaminants during the process – the raw material being, in fact, commercial ferrocolumbium.

The ferro-alloy is chlorinated at 1000° C. (1825° F.). Any aluminum and titanium chlorides present are vaporized from the condensed chlorides at 200° C. in a current of chlorine gas. Ferric chloride is reduced to ferrous chloride, which deposits as fume (along with tungsten chlorides), by heating the vaporized mixture with hydrogen gas at 350° C. (660° F.). This leaves a purified mixture of $CbCl_5$ and $TaCl_5$ gas, and the former is preferentially reduced in hydrogen at 525° C. (950° F.) into solid $CbCl_3$, which in turn is reduced to metallic columbium

(Continued on page 184)

Fig. 3 – Compaction of Slab Enclosed in Deformable "Picture Frame". Dies (flat or recessed appropriately) are made of sintered titanium carbide



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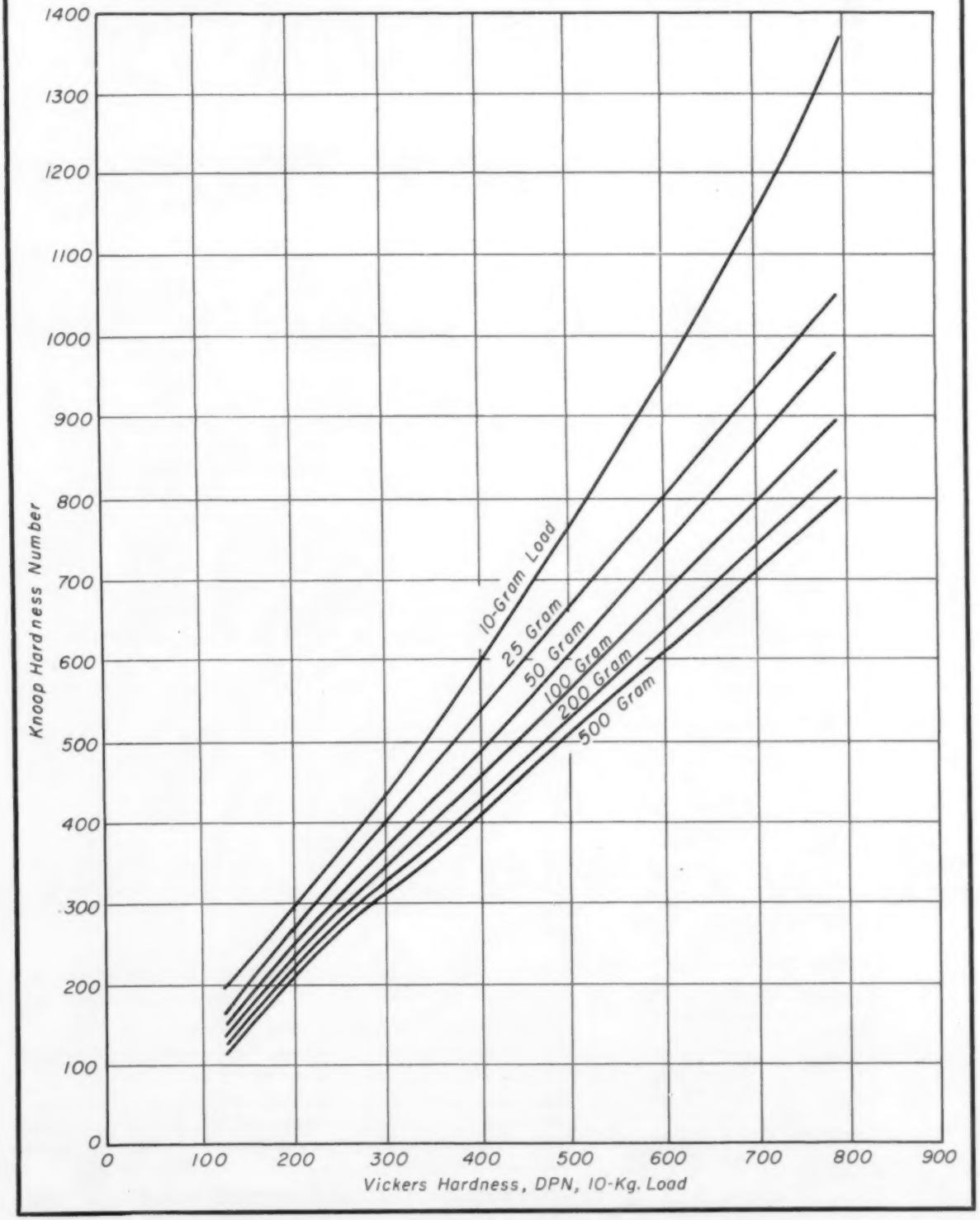
Hardness Conversions, Knoop Versus Vickers

See text on page 97

By Lloyd Emond



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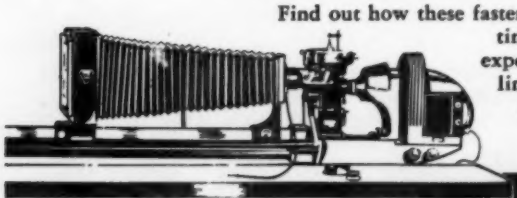

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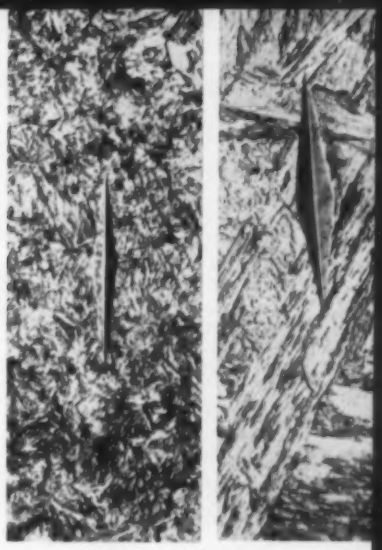
Vickers-Knoop Hardness Conversion

*By LLOYD EMOND**



At Right – High-Carbon Steel (DPH 792) 300 ×, and Low-Carbon Steel (DPH 477) 500 ×

Researchers and inspectors commonly use two methods of measuring hardness of microconstituents of very thin metallic pieces, or for surveying hardness variations (as in carburized cases). One is the Vickers machine, where the indenter is a pyramidal diamond with square base. The other is the Knoop diamond, also pyramidal but having a rhombus base with long diagonal 7.11 times the shorter diagonal.

Relationships between Vickers and Knoop hardness numbers have been determined and published for Knoop loads of 500 g., where close to 1 to 1 ratio exists for the two tests. Once this conversion is made, equivalent values for the various scales can be made by the tables on p. 98 and 99 of the Metals Handbook, 1948 edition, or *Metal Progress* Data Sheet No. 59 (1954 set).

However, it is frequently desirable to use lighter loads than the standard 500 g., so we made a series of tests to determine the relationships between Vickers diamond pyramid hardness (DPH) numbers and Knoop hardness at the lighter loads. Indentations were made and hardness figured from the formula K = L ÷ projected area of indentation; where L is in kilograms and the projected area is in sq.mm.

Three types of material were used in these tests – a low-carbon steel (A 212), a high-carbon steel drill rod, and Monel metal; they were treated as follows:

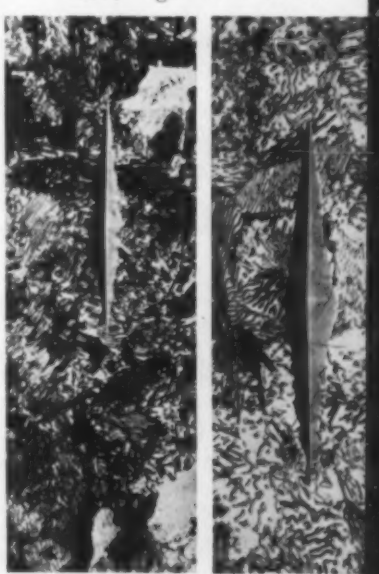
1. A 212, quenched from 1800° F. to produce low-carbon martensite.
2. A 212, furnace cooled from 1800° F. to ferrite and pearlite.
3. Drill rod quenched from 1550° F. to high-carbon martensite.
4. Drill rod air cooled from 1550° F. to fine pearlite.
5. Drill rod, austenitized at 1550° F. and isothermally transformed at 1200° F. to produce coarse pearlite.
6. Monel metal, as received.

After mounting and polishing, several Knoop hardness indentations were made and measured on each specimen using indenter loads of 10, 25, 50, 100, 200 and 500 g., followed by a Vickers hardness test using a 10-kg. load. The Data Sheet, p. 96-B, shows the relationships.

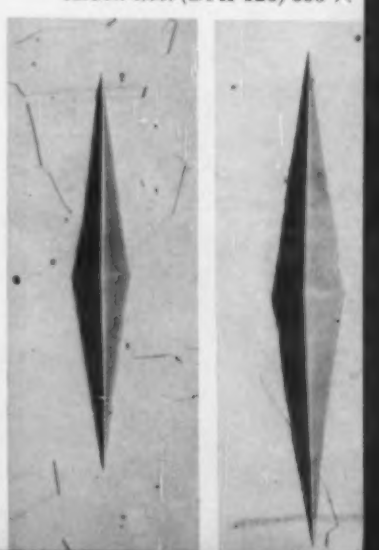
It can be seen that the lighter indenter loads result in higher Knoop hardness numbers. This apparent increase in hardness can be attributed to both elastic recovery of the long dimension of the indentation (the recovery being a larger percentage of the length at light loads than at heavy loads) and the inability to locate the actual ends of the indentation. The indentation length, as determined, may be short by several microns; therefore, at light loads, a greater error results.

Another possible source of error is the influence of surface preparation. When the depth of indentation is only one or two microns, it is difficult to prepare the surface unaffected at least one micron in depth.

While these differences in hardness value do not detract from the value of the test, it is important, even on homogeneous materials, to specify the indenter load when reporting Knoop hardness numbers. The curve in the data sheet should also be useful to correct hardness measurements made on micro-constituents when light loads are necessary.



Below – High-Carbon Steel; 500 ×. Left is DPH 258; right is DPH 211



Below Left – Monel (DPH 149) 500 ×. Right is low-carbon steel (DPH 128) 500 ×

*Metallurgical Research Dept., A. O. Smith Corp., Milwaukee, Wis.

Euratom*

ECONOMIC cooperation with free Europe has been the established policy of the United States since the so-called Marshall Plan (1947), and formation in the next year of the Organization for European Economic Cooperation (OEEC). Steps to remove trade barriers and to regulate production in the heavy industries were taken by the European Coal and Steel Community, instituted in 1952.

Since the six nations Belgium, France, West Germany, Italy, Luxembourg and the Netherlands now have to import about 25% of their energy supply – mostly as oil from Arabia – and these imports are expected to triple in 20 years, attention was turned to atomic power stations. After conferences with experts from Great Britain, Canada and the United States, the six European nations ratified treaties late in 1957 for joint action ("Euratom") to achieve those ends. With the approval of President Eisenhower, American representatives of the State Department and the U. S. Atomic Energy Commission discussed these matters with officials of Euratom and formulated a scheme of cooperation which was sent to the Congress for consideration and approval late in June.

It is proposed to build six to eight reactors, strategically located, ranging from 100,000 to 200,000-kw. electrical output (a total of 1,000,000-kw. capacity) ready for operation in 1963. These will use natural uranium enriched to 3% U^{235} as fuel, and either pressurized or boiling water for the heat transfer medium. These are proven types, developed in the United States. Since one prime objective of the program is to acquire knowledge about new power concepts, the gas-cooled reactor already adopted for the large power program in England is not included. Matching annual contributions of $10,000,000 for research will be made by the European Community and the United States.

The reactors would be built by American firms; they are estimated to cost about $350 per kw. of electricity generated. The required housing, electrical generators and auxiliaries will be built, owned and operated by utilities in the member states. Each utility company will finance the heat-generating portion of its project (reactor) to the same extent as though it were built for carbonaceous fuel – namely $150 per kw. capacity, or a total of $150,000,000. The United States is to arrange for a loan of $135,000,000 through the Export-Import Bank, and the European Investment Bank has been asked to finance the remaining $65,000,000 needed for the total estimated cost of $350,000,000 for the required reactors.

Since the cost of nuclear *fuel* is a major uncertainty, it is also proposed that the United States provide the fuel elements. They will be 0.25 to 0.50-in. rounds and clad either in stainless steel or zirconium, depending on the size and design of the reactor. The initial loading will require about 10,000 kg. of U^{235}, and 20,000 kg. more will be needed for inventory and burn-up during the 20 years of the agreement. This entire amount will come from the quantity already set aside under the "Atoms for Peace" program for distribution to foreign countries. The fuel for starting operation (10,000 kg.) would be transferred to Euratom on a deferred payment basis. The 20,000 kg. needed for burn-up and process losses for 20 years will be paid for at the then current price for U^{235}.

The United States guarantees ceiling costs, minimum life and performance of the fuel elements for the first 10 years, and will process the spent elements, thus recovering the remaining uranium and the plutonium generated during service. The International Atomic Energy Agency would have first option to purchase the latter; otherwise the United States will buy it at the then-established price. In either event, it must be used solely for peaceful purposes.

It is estimated by Euratom's experts that the over-all cost of the nuclear fuel will be 4 to 5 mills per kw-hr. when the uranium is leased for an interest charge of 4%, and the plutonium recovered will be valued at $12 per g. Costs in the Euratom region of imported coal and fuel oil are now 6 to 7 mills per kw-hr., generated therefrom. (The higher cost of power at the busbar – 12.8 mills for nuclear power from fuel oil in plants of equivalent output – is due to capital charges on more expensive nuclear plants – $350 per kw. versus $125. Experience acquired during the operation of the several power plants will probably reduce the fuel cost to 2 to 3 mills per kw-hr., at which time atomic power would compete with conventional installations.)

Euratom has made all the guarantees required by the U. S. Atomic Energy Act that none of the materials supplied will be used for military purposes. It will also establish safeguards conforming to American law and experience. There will be frequent conferences and inspection to assure conformance, as well as verification of Euratom's controls by approved scientific methods.

American laws relating to financial liability for damage to life and property from a nuclear accident will not protect American fabricating firms from accidents to the equipment they build for foreign installations. Pending some international agreement on the insurance problem, it is expected that each contract will include an appropriate indemnity guarantee by the foreign government on whose soil the power plant will be erected.

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*Paraphrase of "24th Semi-Annual Report of the U.S. Atomic Energy Commission to Congress", July 1958, p. 18 to 28, and "Proposed Euratom Agreements", pamphlet dated July 1958 and issued by the Joint Committee on Atomic Energy, Congress of the United States.

Producing for the Supersonic Age

Brazing Alloys for Guided Missiles

*By A. T. CAPE**

Many types of brazing alloys are available and the selection of the right one for the job depends on such factors as kind of materials to be joined, service to which it will be subjected and methods of brazing which are to be used. Modification of standard brazing materials can be used to get added joint strength and other special properties. (K8, T24e; SGA-f)

THE CONSTRUCTION of guided missiles is demanding a diversity of brazing alloys. Service temperature for some of the components is very high. For others the requirements oscillate from extremely low to almost a red heat. Corrosion caused by unusual environments presents problems and oxidation offers serious difficulties.

Brazing materials to be discussed are divided into three groups: (*a*) those for use at relatively low temperatures (includes copper and silver alloys), (*b*) alloys for use up to 1600° F. (and perhaps higher), (*c*) recently developed alloys that have unusual properties.

Low-Temperature Brazing Alloys

Copper is excellent for service at room temperatures and up to 800° F. It requires a moderately high temperature for brazing – 2050° F. If the materials are not oxidized by the atmosphere, brazing is generally effective without using fluxes.

Stainless steels may be brazed in an exothermic gas provided a flux is used and the dark appearance of the part is not objectionable. A well-made butt joint has a strength of 75 to 80% of that of the alloys joined.

*Consultant, Los Angeles, Calif. This and the subsequent article "Welding the Refractory Metals" are adapted from papers presented at First Western Welding, Brazing, and Heat Treating Conference sponsored by Golden Gate Chapter and held at Stanford Research Institute, Menlo Park, Calif., March 27-28, 1958.

Table I – Brazing Alloys for Use at Relatively Low Temperatures

Alloy	Solidus	Liquidus	Brazing Temperature
Copper	melting point	1980° F.	2050° F.
85.0 Ag, 15.0 Mn	1760° F.	1780	1830 to 1880
84.8 Ag, 15.0 Mn, 0.2 Li	1700	1755	1805 to 1855
94.8 Ag, 5.0 Cu, 0.2 Li	1530	1670	1720 to 1770
92.8 Ag, 7.0 Cu, 0.2 Li	1420	1620	1675 to 1725
71.8 Ag, 28.0 Cu, 0.2 Li	1420	1435	1675 to 1725
Fine Ag, 0.2 Li	melting point	1760	1800 to 1825

Other brazing alloys for use at relatively low temperatures are given in Table I. Fine silver and Ag-Li are used to join parts where a fillet is not of great importance. The sudden melting point causes the alloy to flow away; to produce a fillet requires exceptionally close control of temperature. The strength of a well-made butt joint is over 80% of the strength of the joined alloys. This holds for most of the silver alloys.

Ag-Mn and Ag-Mn-Li were favorites for honeycomb construction but so-called crevice corrosion was found to occur and in most of these applications sterling silver containing lithium has been substituted. It forms fillets with ease and is regarded as easy to use in manufacturing.

An alloy having excellent wetting characteristics is 72% Ag, 28% Cu (and with 0.2 Li). But because of the composition's closeness to the eutectic, there is a small temperature range between the solidus and the liquidus, making filleting a problem.

Sterling With Lithium – An interesting alloy is sterling silver containing 0.2% lithium. It brazes without flux as low as 1675° F. It has good strength, and in common with practically all of the silver brazing alloys it does not penetrate into the base. (The Ag-Cu eutectic alloys do penetrate to a small degree.) Given below are typical shear strengths obtained in brazing 17-7 PH with silver alloys:

Alloy	Shear Strength Approx.
92.8 Ag, 7 Cu, 0.2 Li (sterling plus Li)	21,500
71.8 Ag, 28 Cu, 0.2 Li	20,000
84.8 Ag, 15 Mn, 0.2 Li	17,500
94.8 Ag, 5 Cu, 0.2 Li	14,500
Fine Ag plus 0.2 Li	12,000

With a hardenable alloy of the 400 stainless series, a value of 26,000 psi. in shear may be expected for sterling plus lithium. Metals forming the brazed joint are an important influence on joint strength even when there is no apparent dissolving in the brazing alloy. It appears there is no such thing as independent physical properties of any type of brazing alloy.

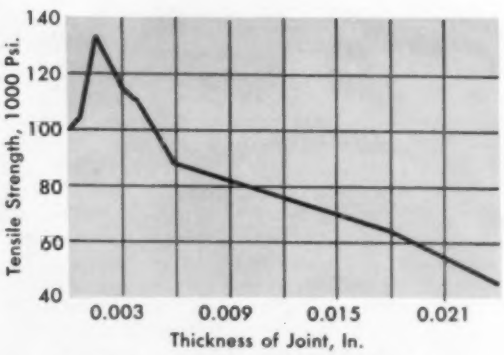


Fig. 1 – Effect of Joint Thickness on Tensile Strength. Stainless (160,000-psi. tensile strength) brazed with silver alloy (70,000 psi.) gives a joint strength of 130,000 psi. if clearance of 0.0015 in. is maintained

Why Brazing Alloys Work

This question is far from answered. Figure 1 is a curve showing the relationship of gap distance to the strength of the joint. It shows that stainless with 160,000-psi. ultimate tensile strength, when brazed with a silver alloy to a piece of the same composition, gives joint strength of 130,000 psi. The strength of the silver alloy, which is doing the joining, is of the order of 70,000 psi. However, the small clearance of 0.0015 in. must be carefully maintained.

There are many forms of joints. One problem arises in a joint with three pieces forming an H. In this case, fillets have to be formed and they must bear any load that tends to break the pieces apart. Here the strength *per se* of the material in the fillet is of vital importance. Tests on brazed honeycomb structures have established that the harder alloys, in conjunction with many (but not all) of the stainless steels, give greater strengths than the softer and more ductile materials. It is also noteworthy that fatigue life is not lowered by the hard alloys. However,

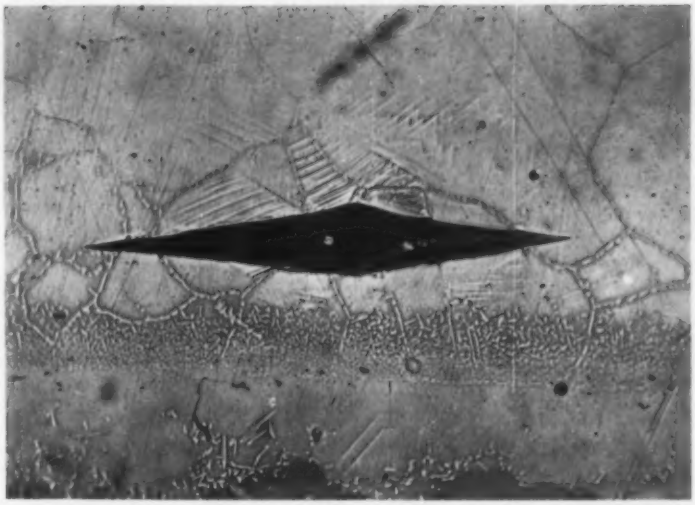


Fig. 2 – Photomicrograph of Heat Treated 17-7 PH Section Brazed With NiB7Cr Alloy. Traces of slip planes caused by the indentation are straight and the structure is austenitic. This technique can be adapted to determining effective penetration

it should be emphasized that the tests were run on the structures as a whole and not on individual parts. Measurements of shear strength of brazing alloys, made in such a way that failure must occur in the brazed joint, give results for the hard, dissolving type of alloy which are much greater than those for soft alloys.

Many tests are used to give a qualitative measure of the properties of brazing alloys. An inverted T is employed so that the flow of the alloy through a joint may be seen which helps determine its ability to form a satisfactory fillet. The vertical section is bent down against the horizontal member. This gives some measure of a property which combines strength, adherence and ductility. It is, however, inadvisable to extrapolate the results into structures of different configurations.

High-Temperature Brazing Alloys

This group, given in Table II, consists of alloys which are constitutionally hard. They are nickel-base alloys which usually contain boron, although there are exceptions to the use of boron, such as the nickel-chromium-silicon alloy and others.

The first four alloys, all of which contain boron, have similar properties. They have a tendency to dissolve the base and to penetrate stainless and some high-temperature alloys. If it were not for the property of dissolving, in some measure, the alloys would be of little value. If joining involves reasonably large sections, then penetrating into the stainless is not deleterious so far as the structure is concerned. The composition of the bonds may vary enormously depending on the types of materials which are being joined. For example, the composition of the brazed joint is different when joining 302 stainless, Hastelloy X or L 605 alloy. Yet, the strength of a well-made joint is of the order of the strengths of the parts joined.

Boron has been accused of diffusing selectively into stainless steel, thus causing embrittlement, but it is clear that the alloy diffuses as a whole. Figure 2 is a photomicrograph of a brazed Section. At the top portion is a brazing alloy of the NiB7Cr variety. The base metal is 17-7 PH, heat treated to the hardened state. The horizontally elongated diamond shape is a Knoop hardness indentation. It will be seen that traces of the slip planes caused by the indentation are straight and the structure is austenitic. Knoop indentations were made further into the base metal at intervals and a point was reached at which the slip planes were no longer straight but irregular, which established the presence of ferrite. The extent of effective penetration was defined by one Knoop indentation which exhibited straight slip planes on the side nearer to the braze and irregular slip planes on the other side farther away. The formation of austenite could not be due to boron alone; the brazing alloy itself has travelled into the base metal to cause the effect. Chemical analyses of brazed joints show that both nickel and boron are present.

Boron Properties – A characteristic of the boron alloys is their tendency to dissolve and diffuse into steels. The phenomenon is both their strength and weakness – making them ideal for joining large sections but if care is not taken

Table II – High-Temperature Brazing Alloys

Designation	Composition					Melting Point	Flow Point	A.M.S. Specification
	Ni	Si	B	Cr	Other			
NiB15Cr	72.50*	5.00	3.50	15.00	Fe, Mn	1820–1830	1840	4775
NiB7Cr	82.00	4.50	2.90	7.00	3 Fe, Mn	1790–1800	1825	4777
NiB	91.25	4.50	2.90		Fe, Mn	1790–1800	1820	4778
Ni low-B	93.25	3.50	1.90		Fe, Mn	1900–1910	1930	4778
NiCrSi	62†	19		10	Fe, Mn	2150	2150–2200	
	62.5‡	4.5		4.5	8.5 Mo, 18 Mn, bal Fe	2100	2150	

*Melting point depends on method of manufacture and figures are published giving considerably higher values.

†It has been reported that if this alloy is vacuum melted its melting point may be as much as 100° F. lower.

‡Molybdenum is said to offset the embrittling effect of the silicon.

disastrous for thin ones. In a honeycomb structure, the foil may be dissolved entirely. If the alloys are to be used for thin sections, then it is necessary to control accurately the amount of brazing alloy used, temperature and time at temperature. The last factor is the most difficult to control since the mass of the part may be the determining point. Nevertheless, honeycomb structures with good physical properties are being produced using the NiB15Cr, NiB7Cr and NiB alloys.

One company, a builder of missiles, has settled on the use of the NiB7Cr alloy. Photographs in Fig. 3, 4 and 5 show various structures put together to establish the procedures for brazing and the alloys to be used. Here is a section quoted from the report of the metallurgist at this company.

"Brazing using high-temperature nickel alloys in heat exchanger units for rocketry is of particular importance, not only because of their resistance to highly corrosive media, but also because they join these thin parts with a complete elimination of the drip-through which is normally encountered in welded structures of this type. Brazing gives improved heat transfer characteristics. The NiB7Cr and the NiB alloys are of particular importance because they, unlike most of the other types of high-temperature nickel brazing alloys, have constant flow points (within 10° F.) from batch to batch, and flow is obtained at much lower temperatures. This is significant because undercutting is reduced to a minimum and dripping is readily controlled in long vertically brazed sections."

This metallurgist also studied the joining of Inconel X. He found the most satisfactory method to be as follows:

1. Prepare freshly ground surfaces.
2. Mix a saturated solution of sodium fluoride with NiB7Cr powder.

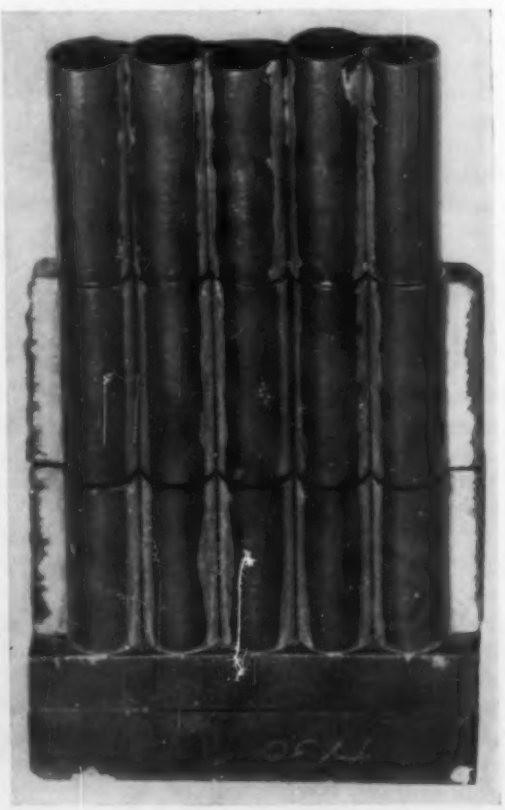


Fig. 3 – This Heat Exchanger Section Consists of Type 347 Tubes Brazed at 1900° F. to Timken 17-22 AS and 4130 Base Plates. Part was heat treated to Rockwell C-37 to 39 after brazing and no cracking occurred. Piece was sectioned to show cross section of joint

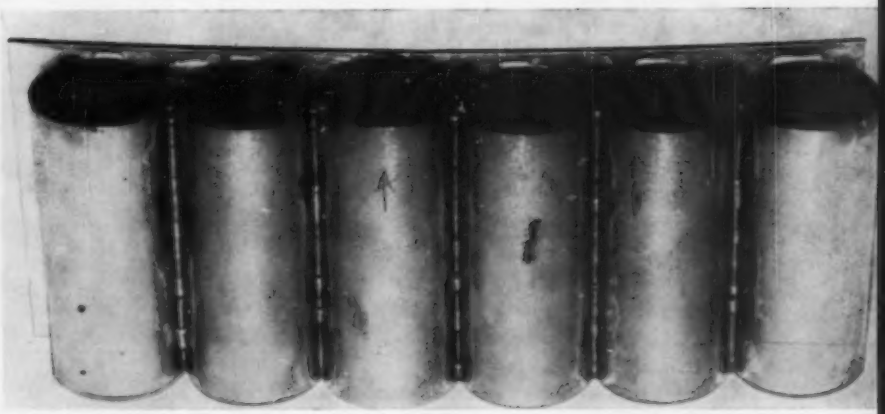


Fig. 5 – This Missile Assembly Is Used With Red Fuming Nitric Acid. It's made of 17-7 PH, brazed at 1950° F. with NiB7Cr, and heat treated. Full joint was required which was obtained by applying braze in local 1-in. patches which were allowed to flow and fill the balance of the joint

Fig. 4 – These Tubes Are About 20 In. Long and 8 In. in Diameter With a Wire Helix Extending the Length of the Tube. Both tube and wire are made of 17-7 PH, joined by NiB7Cr brazing alloy. Part was hardened after brazing and there was no evidence of cracking or embrittlement

3. Braze in hydrogen with a dew point no higher than minus 60° F.

4. Keep the amount of brazing alloy used as small as possible.

Figure 6 shows structures of typical Inconel brazes made by this procedure.

Selection of Brazing Alloy

Reasons for selecting one of the various brazing alloys are often not well defined. There are, however, some well-defined differences between the alloys. The 15% Cr alloy has a higher melting point than any of the others with the exception of the low-boron, nickel alloy. The latter is not as active as the other members of the group and is usually used where an inherent element of ductility is required. The 15% Cr alloy will dissolve base metals rapidly and depends on the alloy formed by this process for its effectiveness. The NiB7Cr alloy is less active than NiB15Cr and melts at a lower temperature. NiB alloy is a little less active than the NiB7Cr. However, to be effective it must also dissolve to some extent the surfaces of the joint.

It might be thought that the material which reacts least with the base is the best one to use. This is not necessarily so. Studies have been made to compare the strength of honeycomb structures using NiB7Cr with identical structures brazed with alloys that wet, but do not dissolve. These are summarized below:

Material	Brazing Alloy	Facing Stress
	At Room Temperature	
321	Nonalloying	34,600 psi.
	NiB7Cr	48,200
17-7 PH	Nonalloying	66,000
	NiB7Cr	104,700
	At 800° F.	
321	Nonalloying	26,350
	NiB7Cr	36,150
17-7 PH	Nonalloying	53,750
	NiB7Cr	73,250

In all tests size of cell was ¼ in., foil thickness 0.002 in. Similar results have been obtained by other experimenters, yet the fear of the effects of boron on the structure has prevented general use of the active alloys for brazing honeycomb structures. Careful studies of brazed sections have never revealed any embrittling effect because of boron in the brazing alloy.

Brazing Alloys With Unusual Properties

Some materials are difficult to join under almost any conditions. One of these is 17-4 PH, but by using a modification of NiB alloy containing 2% Ti, the problem was solved. Joints made

after the technique was established were so sound that on heat treating the part to a hardness of Rockwell C-37 to 40, Charpy values were 124 ft-lb. at right angles to the braze and 42 across the brazed joint. The minimum requirement specified was 15 ft-lb.

Additions may be used to inhibit the dissolving and penetrating effects of alloys containing boron. For example, 10% Co will prevent dissolving but to a small extent with many types of stainless steels. The alloy gives unusually high strength when joining materials such as Inconel 700. Cobalt may be used either with the NiB, NiB7Cr or NiB15Cr systems. (Other elements are even more effective but patent regulations in some foreign countries prevent disclosure of the alloys at this time.)

Gold Alloy – An alloy with the composition 72% Au, 6% Cr, 22% Ni has been used experimentally for the last two years. It dissolves but does not penetrate; the amount of base dissolved is 0.003 in. at 2050° F. for an hour. At the normal brazing temperature of 1900° F., the solution of the parent metal is very small in amount and consequently the alloy is valuable for joining thin pieces of steel.

The tensile strength at 1200° F., after seven days at 1600° F., is 40,000 psi.; at 1600° it is 22,000 psi. (The tests were made using 18-8 stainless.) An extraordinary property of this alloy is its ability to braze graphite to many types of stainless steels.

An alloy of 68% Mn, 32% Ni is by no means new but it has not been used to any extent. There were difficulties in manufacturing both the powder and the foil, but the problems appear to have been solved. Addition of 1% Co to this alloy improves its properties, particularly in cases where the atmosphere is not perfect. With 16% Co, the alloy is particularly useful for joining stainless steels containing aluminum and titanium.

These alloys stand out for their ability to fill wide gaps (0.010 to 0.015 in., and recently gaps as large as 0.060 in.) without flowing away from the joint. Excellent fillets are formed and the strength of the alloy in the joint is unusually high. There is a small tendency to dissolve the base metals, but only to a minor extent. The inverted T test referred to earlier gives a measure of the properties of these alloys. The hardnesses found in joints vary only little; the MnNi alloy with 1% Co is between Vickers 115 and 120 while the alloy with 16% Co has a hardness of Vickers 190 to 200, independent of the type of materials being joined.*

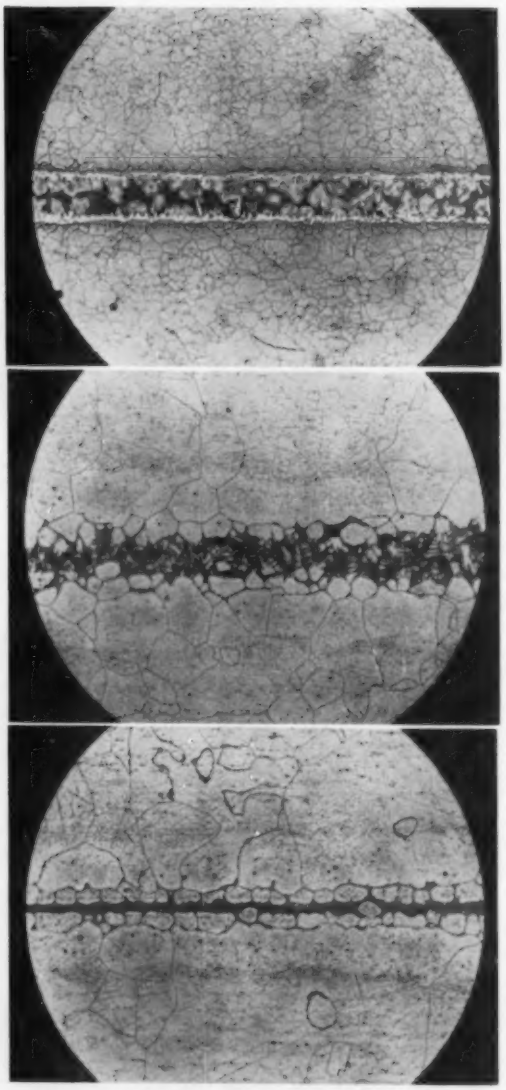
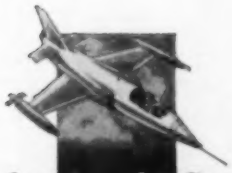


Fig. 6 – Photomicrographs of Inconel X Joints. (Top) Gap clearance, 0.006 in., brazed at 1850° F., 10 min., using NiB7Cr. (Middle) Same as above, heat treated for 1 hr. at 2000° F. after brazing. (Bottom) Gap clearance 0.002 in., brazed at 1850° F., 10 min., using NiB7Cr. Heat treated for 1 hr. at 2000° F. after brazing

*The author thanks the following for the use of photographs, and supplying information: R. C. Kopituk, Manager of Materials, Reaction Motors Inc., Rockaway, N.J.; C. V. Foerster, Technical Dir., Coast Metals, Little Ferry, N.J.; Hexcel Products Inc., Oakland, Calif.; A. M. Setapen, Manager Engineering Div., Handy & Harman, New York; and John V. Long and George D. Cremer, Solar Aircraft Co., San Diego, Calif.



Producing for the Supersonic Age

Welding the Refractory Metals

By L. F. YNTEMA*

Tantalum, columbium, molybdenum and tungsten are used on many devices operating at high temperatures because of their high melting points and high-temperature strength. Because of their reactivity with air and their affinity to low-melting metals, they require careful control of welding variables. (K-general; EG-d, Ta, Cb, Mo, W)

THE NAME refractory metals is usually applied to the high-melting metals of Groups IV, V and VI in the periodic table and more specifically to columbium, tantalum, molybdenum and tungsten. Their melting points are 2415° C. (4380° F.) for columbium, 2650° C. (4800° F.) for molybdenum, 3000° C. (5430° F.) for tantalum and 3400° C. (6150° F.) for tungsten. These metals possess certain properties associated with high melting points, such as low vapor pressure and good high-temperature strength, as well as other properties, such as a high degree of formability into rolled and drawn shapes, that make them attractive as structural components in many devices. They can be joined by riveting and brazing but, obviously, their range of usefulness is broadened by the application of welding techniques for their fabrication.

Both tantalum and columbium react with hydrogen, oxygen, nitrogen, the halogens, and the oxides and hydrides of carbon. The only gases with which there is no reaction are the noble gases. They form alloys with most metals, the general exceptions being the metals of Groups I and II in the periodic table of elements. To obtain a good weld, the hot metal must not come into contact with any reactive gas or with a metal with which it can alloy or adhere.

Three methods are successfully applied: resistance welding, submerged-arc welding, and inert-gas-shielded arc welding.

In resistance welding, the high electrical resistance at the point of contact of two parallel overlapping surfaces instantaneously raises the temperature of the lapping surfaces of metal to the plastic range and fusion or welding is achieved by pressure. It is apparent that the initial pressure must be high enough to establish electrical contact but must not be so high that too small a resistance is produced between the parts prior to welding. The weld may cover a small area or spot or may take the form of a seam. The depth of penetration can be controlled. Within reasonable limits, sheets of a wide range of thickness can be welded.

Two types of circuits are used. In the one, a stepdown transformer circuit produces a high-amperage, low-voltage current of short duration. The metal, usually two overlapping sheets, is pressed between two conducting blocks, usually copper or a copper alloy. Very thin sections can be welded in air or in a blanket of inert gas; thicker pieces are submerged in air to insure rapid chilling. When a tube is to be produced by seam welding, sheet is rolled into tubular form and placed over a heavy copper rod or mandrel, which serves as one electrode. The other electrode, a wheel, is run over the

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overlapping edges of the metal. The succession of electrical discharges produces a seam.

It should be noted that the surfaces of the metal to be joined are best conditioned by thorough cleaning and then by rubbing with a fine abrasive cloth or paper to remove foreign material and to remove any oxide film.

This seam welding process is economical and it produces a perfect union. Its one major defect as a means of fabrication is that there is an overlap of double wall thickness and a recess where the sheet projects beyond the weld area.

The second circuitry is the stored energy or condenser discharge type. The sequence of charge and discharge of the condensers is controlled by a suitable timing device. This method permits very close control of the degree of penetration of the molten zone. It can be used for welding overlapping sheets, for welding a wire to a plate and for joining the ends of two wires. It also affords a means of joining columbium or tantalum to another metal, such as nickel.

The submerged-arc process (Fig. 1) has been standard practice in the tantalum industry for many years. A major advantage of the technique is that it is done "free hand" and therefore can be employed in the welding of complicated parts in which the operation cannot be mechanized. A small amount of carbon penetrates the weldment, but the performance of the welds in many industrial uses has amply demonstrated the practical value of the process.

In the operation, the work is completely submerged in liquid carbon tetrachloride. The edges of the pieces to be joined are placed parallel to each other. A carbon rod is one electrode and the work the other. Welding unit uses 25 to 30 v. and 20 to 40 amp., d-c. These values are not absolute but are cited to indicate their order of magnitude.

The third welding method is the inert-gas-shielded arc process. A direct current arc between a refractory metal tip, preferably tungsten, and the work produces the molten pool. This process is particularly useful in joining sheets placed edge to edge. It has been used to weld flat sheets, and to produce circumferential welds that join the ends of tubes or cylinders. It has been used to form tubing with a longitudinal weld and can be used to weld tubes onto headers.

When no filler rod is used, the thickness of the weld is the same as that of the stock. In the case of tantalum and columbium, the weld has the ductility of completely recrystallized metal and can be worked by rolling or drawing. It is good practice to use completely annealed stock so that the weld may have essentially the same physical properties as the parent metal. Since it is usually slightly softer, a light peening will produce a matching hardness. In addition, the resistance to solution and the other chemical properties of the weld are identical with those of the parent metal.

The operation is adaptable: A uniform automatic weld can be produced by maintaining control of variables such as rate of travel, amperage, voltage, and arc length.

In practice, a conventional inert-gas, tungsten-tipped electric torch is used. The work is so positioned that the two edges are in contact in the same plane as shown in Fig. 2. The work must be held fixed in place. If it is not, the contraction of the weld, as it solidifies, will draw the pieces out of alignment and the edges will overlap. The edges to be welded must not be in contact with any part of the welding fixture and therefore the area to be welded is positioned over a slot approximately $\frac{3}{8}$ in. wide and $\frac{1}{8}$ in. deep. The torch is fitted into the lid of the chamber that is filled with helium. The helium flow rate is such that a positive pressure is maintained. Depending on the size and shape being welded, a separate flow of helium may be directed into the slot in the fixture.

The tungsten tip is the cathode. To prevent contamination of the weld with tungsten, the arc is initiated by a high-frequency discharge which is stopped when the arc is established. An alternating current may be used but is not as satisfactory because a higher amperage is re-

Fig. 1 – A Unique Submerged-Arc Welding Process. A tantalum repair patch, shaped like a cup, fits the turned-up hole in this tantalum acid cleaning tank. The joint is then immersed in carbon tetrachloride and the edges are welded with a carbon electrode. A suction hose draws off the noxious fumes

quired and because there is more erosion of the tungsten electrode and an accompanying danger of contamination of the weld.

The lower limit of sheet thickness that can conveniently be welded is 0.013 to 0.015 in. With thinner sheets, it is difficult to insure that the molten pool will bridge the space without breaking. The upper limit of thickness is probably the amount of current available to obtain complete penetration.

The potential drop across the arc is 26 to 30 v. The amperage that is required varies with the thickness of the sheet being welded, the rate of travel of the torch in respect to the weld, and also with the general thermal conductivity of the whole assembly. Typical data are as follows: rate of travel, 8 in. per min.; current for 0.015-in. sheet, 21 amp.; for 0.020-in. sheet, 35 amp.; for 0.040-in. sheet, 100 amp.; for 0.05-in. sheet, 120 amp.

Manual welding has been used to join edges placed in parallel planes. Thinner stock, 0.005 or 0.006 in., can be welded in this manner. This procedure is useful in welding tubes into headers. A cup is formed in the sheet that forms the head of the assembly. The bottom of the cup is cut off and the edges are flared to a size that will form a close fit with the tube. The tube is inserted and the weld can then be made. An amperage-limiting device must be included in the circuit when stock is being welded "free hand".

Mention has been made in the literature of the use of pure tantalum rod as filler rod.

The purity limits of the shielding gas have not been definitely established. High-purity helium can be used without further treatment. At one time the helium was passed through a heated sponge of tantalum scrap wire; although the wire became embrittled after several hours, no difference was noted in the quality of the welds.

It is important to protect tantalum and columbium weld metal during cooling down to about 570 to 750° F. to prevent contamination.

The reason for occasional porosity in welds is still obscure to my knowledge. It has not been related to any measurable differences, either chemical or physical, between good welding stock and stock that gives a poor weld. The best test would appear to be the empirical one of running a test weld.

The welding techniques that are available for welding tantalum and columbium afford an efficient means for fabrication of these metals.

The welding of molybdenum has been the topic of a rather extensive series of investigations by both government agencies and private industry. The basic problems appear to be well defined. The mechanics of the operations are essentially similar to those discussed for tantalum and columbium. The basic differences of molybdenum and the other two, particularly the sensitivity of molybdenum to trace impurities (especially oxygen), appear to present the real problem.

Commercial tantalum and columbium are ductile in the annealed and fully recrystallized state. Therefore the weldment is ductile, provided the operation is correctly performed. On the other hand, recrystallized molybdenum is normally brittle. It is only by the most rigorous exclusion of impurities, particularly oxygen, both in the parent metal and in the welding process, that ductility can be attained.

Fig. 2 — Joining Columbium Sheet by the Inert-Gas-Shielded Arc Process. Sheets are strapped to a large rotating drum. The welding torch is enclosed in a chamber or dry box containing helium. The underside of the joint is also shielded with helium

Fig. 3 – Making a Longitudinal Weld in Molybdenum Cylinder by Inert-Gas-Shielded Arc Process. Details of the purge chamber and its sliding cover are shown

It has been suggested, and very probably correctly so, that the brittleness is related to segregation of impurities in the grain boundaries during recrystallization and freezing, and that this is in turn related to the low solid solubility of oxygen and other impurities in molybdenum.

Welding of molybdenum can be performed by resistance, by condenser discharge and by arc welding methods that are basically similar to those mentioned for tantalum welding. In resistance welding, the surfaces must be cleaned to remove oxides and other impurities. A sulphuric-nitric-chromic-hydrofluoric acid dip or a molten caustic dip may be used. In some instances it is good practice to sand-blast or to dimple one of the surfaces being welded. Resistance welding has been practiced in the assembly of small molybdenum parts for years and is a standard operation.

In the inert-gas-shielded arc process, where the parent metal is joined by a section that has been completely molten, the characteristics of molybdenum in the form of large crystals become a major consideration. Three undesirable effects may be noted: porosity, either in the weld or in the boundary between the fused and unfused metal; hot cracking; and loss of ductility in the weld, as compared to the parent metal. The important considerations in producing a satisfactory weld are the purity of the parent metal and the shielding gas, the effects of deoxidants, and the treatment after the welding operation has been completed.

Three nonmetallic elements that have a deleterious effect are oxygen, nitrogen and carbon, in decreasing order of importance. Oxygen content of the order of 0.0001% will raise the bend test transition temperature to 180° C. (360° F.) from −70° C. (−90° F.), the value for pure metal. A nitrogen content of 0.0035% will raise the transition temperature to 30° C. (86° F.), and a carbon content of 0.02% produces the same effect.

Obviously the purity requirements extend to the surface of the metal as well as to the mass of metal itself. In hot rolling and otherwise working molybdenum, surface oxides are formed which must be removed so that the welding operation is done on clean metal. Electrolytic polishing or the acid treatment previously mentioned can be used.

The use of pure argon or helium is essential. An oxygen content below 0.02% and nitrogen below 0.05% is required. Conventional methods of purification may be used, such as passing the gas over a hot reactive metal.

Surprising results have been obtained in increasing the cold bend ductility of a weld by grinding off the surface layer to produce a smooth surface and to eliminate microcracks. It is also desirable to stress-relieve by heating the work, bearing in mind that the recrystallization temperature of molybdenum is about 1000° C. (1830° F.).

A number of items have been successfully welded using molybdenum sheet. Tubing and cylinders have been made with a longitudinal weld (Fig. 3); nozzles and flame holders have been fabricated.

Comparatively little has been done on the welding of tungsten. Its high melting point imposes obvious difficulties. It is probable that problems of purity will be met that will be similar to those mentioned in the welding of molybdenum.

Present and Future Uses of Titanium

*By PAUL M. TYLER**

Titanium sheet and forgings now cost so much that uses are restricted; 90% of American production goes into jet engines for the Air Force. In a mature industry with integrated plants, costs would be cut to one fifth, thus opening large new markets in chemical equipment and wheeled vehicles. (A4s, 17-57; Ti)

"WIDESPREAD ACCEPTANCE of titanium as an industrial material is dependent upon reduction in production cost, improvement in quality and uniformity of metal, more efficient utilization of scrap, development of alloys for specific uses, increased knowledge of properties, exploration of new applications, and improved fabrication techniques."

So the Bureau of Mines summarizes the situation. This is a large order, and progress toward these objectives has been quite uneven, as indicated in the two previous articles in this series. This final one will discuss costs and uses already proven satisfactory.

Cost of Sponge

Production costs and prices of sponge titanium have been progressively reduced and quality improved, thus confirming the conservative expectations of a few years ago. Up until 1954, from 1948 when commercial production was first announced by Du Pont, the price of titanium sponge was $5 per lb. in 100-lb. lots and $7.50 per lb. for smaller lots. Subsequent price changes for Grade A-1 (0.30% Fe) and Grade A-2 (0.50% Fe) in 100-lb. lots have been as follows:

EFFECTIVE DATE	GRADE A-1	GRADE A-2
April 1, 1954	$4.72	$4.46
Dec. 1, 1954	4.50	4.00
April 1, 1955	3.95	3.50
Nov. 1, 1955	3.45	3.15
Dec. 3, 1956	2.75	2.50
June 3, 1957	2.25	2.00
April 1, 1958	2.05	1.85

Quality also has been progressively improved so that Grade A-1 has 0.20% max. Fe and Brinell hardness 125 max., while Grade A-2 has 0.45% max. Fe and hardness less than 170.

It will thus be seen that a mid-1952 prediction to the Department of Defense, by an advisory committee headed by Zay Jeffries, has come to pass, namely, that "anticipated improvements in the Kroll process are expected to permit a selling price of $2 per lb., plus or minus $0.50, on the basis of 10,000 tons a year production and no change in the value of the dollar". Table I shows that, on the basis of present technology and scale of production, even lower prices seem reasonably to be expected. (Professor Kellogg, quoted in Table I, is chairman of the Titanium Advisory Committee, and Mr. Porter made his studies while working for a doctorate at Rutgers University.)

Professor Kellogg emphasizes that a mature industry will include individual plants making 20,000 to 40,000 tons of sponge annually. (Compare this with present plants making 6000 to 10,000 tons annually.)

The cost estimates in Table I are by no means out of line with current thinking. Even on much smaller-scale operations, Kroll sponge could probably be sold commercially at less than

*Staff Consultant, Materials Advisory Board, Div. of Engineering and Industrial Research, National Academy of Sciences, Washington, D.C. This is the third article taken from his extensive report submitted to the Assistant Secretary of Defense (Research and Engineering) on Feb. 14, 1958.

Welding Tube-Ends Into Tube Sheet (Within an Argon Chamber) for a Condenser. (Courtesy E. I. du Pont de Nemours & Co.)

$1.50. Newly developed electrolytic processes promise to achieve an ultimate cost of less than $1 per lb., and might even go as low as $0.80 per lb.

Cost of Mill Products

Prices for mill products have been sharply reduced since 1953, but small volume production and technical difficulties have stood in the way of prices competitive with stainless steels and high-strength alloy steels. Base prices, in dollars per pound, for commercially pure (unalloyed grades) of titanium, have been as follows:

Form	1954	1957
Forging billets	$ 9.00	$ 6.00 to 6.25
Hot rolled bars	9.00	6.15 to 6.40
Plate	12.00	8.00 to 8.75
Sheet	15.00	10.10 to 11.10
Strip	15.00	9.50 to 10.00
Wire	11.00	7.50 to 8.00

Advanced and specialized mill practices will undoubtedly result in lower prices in the future.

Extras over the base prices are about the same for titanium as for steel products. Gage extras on sheet range from $0.50 to $6.75 per lb. and width extras (over 36 in. to 42 in.) up to $2 per lb. Shearing to widths under 24 in., lengths over 96 in., quantities under 10,000 lb., special finishing, or special flatness requirements all call for additional extras. Actual prices paid by the airframe industry therefore range between $7 and $15 per lb. This immediately

Table I — Estimated Costs of Sponge by Kroll Process

	By H. H. Kellogg				D. F. Porter	
	Actual, 1956		At Maturity		Maturity	
Production	3600 tons		200,000 tons		75,000 tons	
Raw materials						
Ore (95% TiO_2)	$0.194		$0.043		$0.06	
Chlorine	0.159		0.03		0.03	
Magnesium	0.469		0.09		0.09	
Carbon, argon, misc.	0.043		0.023		0.03	
Subtotal		0.865		0.186		0.21
Electricity and water	0.110		0.113		0.085	
Depreciation and amortization	1.350		0.079		0.11	
Labor and overhead			0.347		0.45	
Subtotal		1.460		0.539		0.645
Oncost						
Net profit	0.324		0.20		0.20	
Income tax	0.351		0.22		0.22	
Subtotal		0.675		0.42		0.42
Total selling price, per lb.		$3.000		$1.15		$1.28

Table II – Short-Time Tensile Properties (Units of 1000 Psi.)

	Room Temperature			At 800° F.		
	Ultimate	Yield	Elong.	Ultimate	Yield	Elong.
Titanium alloys						
Target	180 (290)*	160 (258)*	10%	130 (210)*	105 (170)*	15%
Alloys in Sheet Rolling Program						
6% Al, 4% V	170 (298)	155 (264)	10	115 (202)	100 (176)	10
16% V, 2.5% Al	170 (290)	150 (258)	5	130 (210)	120 (204)	7
4.5% Al, 3% Mo, 1% V	170 (290)	150 (256)	10	100 (171)	80 (137)	15
Beta alloy (25% alloy additions)	210 (335)	185 (295)	10	—	—	—
Steels						
17-7 PH (semi-austenitic)	245	225	6	130	105	14
14% Cr (martensitic)	247	195	10	165	125	10
Hot work die steel	290	238	10	225	200	9
A.I.S.I. 4340 (Ni-Cr-Mo)	250	225	10	180	—	—

*In parentheses are given equivalent values for steel required to maintain the same strength-weight ratios as the titanium alloys.

indicates why manufacturers tend to use stainless steels (base price on Dec. 2, 1957 of $0.655 per lb.) rather than titanium, even when full allowance can be made in the design for the latter's low specific gravity.

Rolling mill technology for titanium alloys has improved steadily. At present, titanium is largely handled in plants designed for stainless steel. Re-equipment of such a steel mill for titanium only was not completed until late 1957. (This was by Titanium Metals Corp. of America.) Apart from the loss of time in changing from the regular business of rolling stainless to a small run on titanium, the characteristics of the two metals are too incompatible for economical co-production. Titanium needs smaller reductions (than stainless steel) in press and hammer forging and blooming to minimize edge cracking and subsequent conditioning. For larger titanium ingots, rolling mill equipment for steel may not be powerful enough for suitable reductions of titanium in a single heat. Moreover, titanium requires more frequent conditioning and much closer temperature and atmosphere control.

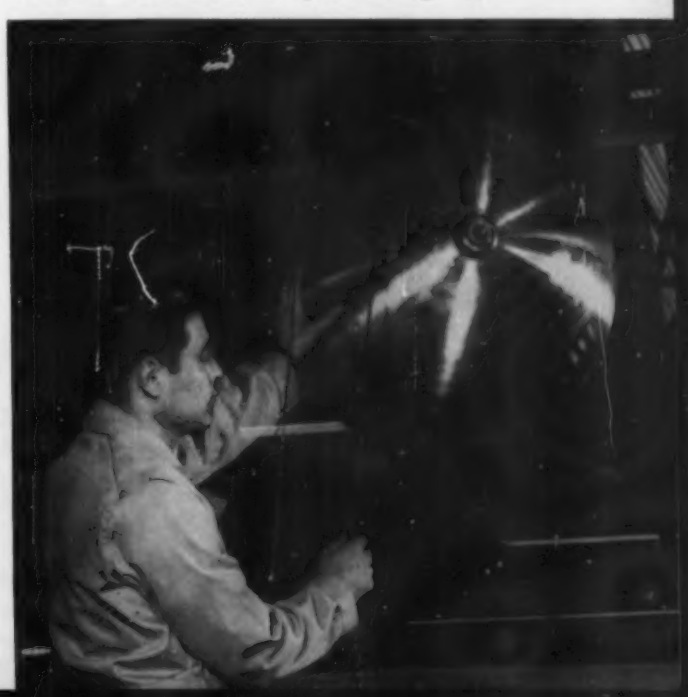
A recent limited survey by Battelle Memorial Institute indicated that fabricators can now supply high-strength titanium alloy sheet at the upper range of gages (about 0.020 to 0.050 in.) with existing equipment, but that mills specially designed for rolling gages, widths, and tolerances comparable with those of competitive high-strength stainless and other alloy steels will not be available until 1960.

Professor Kellogg has made some predictions based upon what may be expected in a mature industry comprising fully utilized integrated plants having capacities ranging from 20,000 to 40,000 tons a year. Under such circumstances, he anticipates that the cost of titanium mill shapes will be about four times those of stainless steel. Based on sponge metal at $1.15 and purchased scrap at $0.80 per lb., he thinks that forging billets will cost $1.78 per lb., plates $2.06 and sheets $2.34 per lb.

Uses

In view of the price handicap, it is not surprising that so far the only considerable use of titanium has been in aviation where weight saving is at a premium and temperatures to be

A Pressure Vessel for Propellant for a 5500-Mile "Atlas" Missile. (Courtesy Rheem Mfg. Co.)



Titanium Sheet Is Rolled on the Old Hand Mills. (Courtesy Titanium Metals Corp. of America)

withstood in use are so high that the available alloys of the other light metals, aluminum and magnesium, have undesirably low creep strength.

Civilian – Titanium has been used in marine fittings, electroplating racks, heat exchangers, pump impeller blades, piping, tank linings and miscellaneous chemical plant equipment. It has phenomenal resistance to salt water, acids and many chemicals, but cheaper materials are more economical unless conditions are exceptionally severe or shutdowns for replacements cannot be tolerated. For example, *Rem-Cru Review* describes a titanium pump impeller costing $390 instead of $150 for a Ni-Cr-Mo alloy. However, the titanium version required no maintenance in 2½ years and is expected to last 10 years, so its annual cost is estimated at $39 while the annual bill for the other has been $420. In food processing, titanium equipment not only lasts indefinitely but does not change the color or flavor of the food. Miscellaneous uses in considerable number have required only insignificant quantities of metal or are merely in the experimental stage. The largest civilian order to date was placed in September 1957 by Freeport Sulphur Co. for seven miles of tubing for heat exchangers in their Cuban cobalt-nickel plant.

Competition With Steel in Aircraft – The major structural metals in aircraft and jet engines are aluminum and magnesium at temperatures below about 400 to 500° F. (even 600° F. for lightly loaded elements) and titanium and stainless steels from there up to about 1200° F. Above about 1600° F. only the most refractory metals, cermets, ceramics and graphite can be considered.

Whereas the upper range of usefulness of titanium alloys may be raised to 1000° F. and may even reach 1400° F. for short exposures, better iron alloys are being developed which easily withstand these temperatures and possess enough strength to offset to a considerable extent their higher density. It is often said that 28 lb. of titanium has the strength of 50 lb. of steel, but this wide advantage in strength-to-density ratio is less today than it was a few years ago.

At present, the principal all-around competitors of titanium alloys* in airframe applications are the precipitation hardening stainless steels. Their service temperature ranges are about the same as that of present alpha-beta titanium alloys. Their strength-weight ratios are considerably poorer than heat treated titanium but their cost is very much less. Other alloy steels which have been talked about, but not used as

*Since 60 to 80% of the structural weight of recent fighter and bomber aircraft is sheet, the titanium sheet alloys are of most importance.

(Continued on p. 170)

Recent Statistics on Metallurgical Education

*By W. O. PHILBROOK**

Nearly 10% more degrees in metallurgy were granted in 1957 than in 1956. The number of B.S. degrees fell just short of 600, but was up 9.5% over the previous year. Masters', with 176 degrees, were up 8%. Doctors' totaled 83, up 9%. (A3g)

IN AN ARTICLE on this subject in *Metal Progress* for November 1957, Michael B. Bever analyzed statistics on education in metallurgy through the academic year 1955-56. The present report gives data on metallurgical education in the United States for last year. It is based on a questionaire sent to 61 institutions concerning degrees awarded for the academic year 1956-57. It is believed that this represents a 100% sample of all degrees granted in metallurgy or metallurgical engineering in the U.S. for this period. Although the data reported here have been reviewed by the full committee, the chairman accepts responsibility for interpretation or opinions expressed in this summary.

*Professor of Metallurgy, Carnegie Institute of Technology, Pittsburgh; Chairman of Committee on Metallurgical Statistics, Foundation for Education and Research. Other members of the Committee: Michael B. Bever (Massachusetts Institute of Technology), Alfred Bornemann (Stevens Institute of Technology), Morris E. Nicholson, Jr. (University of Minnesota), and John P. Nielsen (New York University).

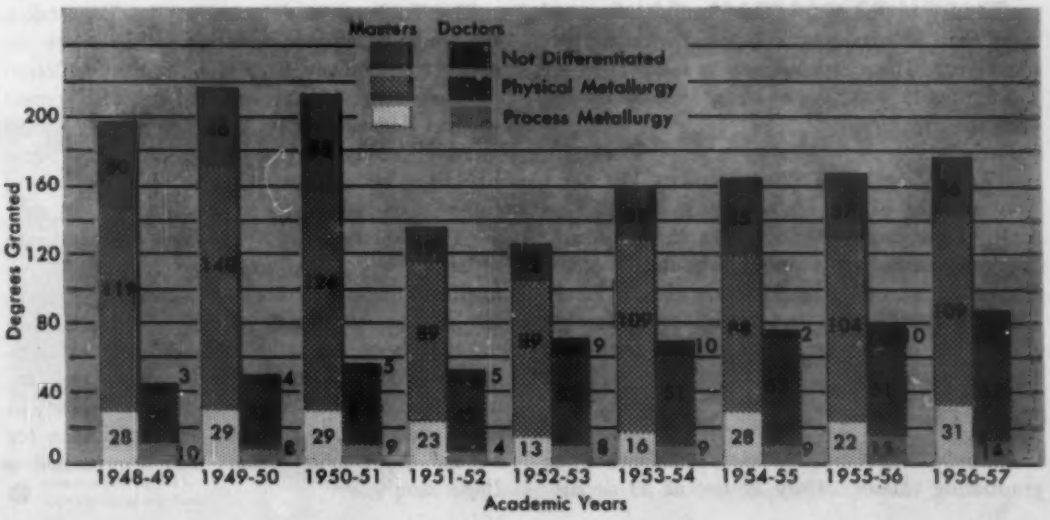


Fig. 1 – Graduate Degrees Granted in Metallurgy in the U.S., 1949 Through 1957. Light color bars represent Masters' degrees; darker bars Doctors'

First Positions Taken by Students After Graduation

	Bachelors		Masters		Doctors	
	1956-1957	1954-1956	1956-1957	1954-1956	1956-1957	1954-1956
Industry, operations	26.8%	27.6%	14.5%	12.1%	0.0%	4.8%
Research and development	13.7	17.9	29.1	33.2	59.1	56.6
Not differentiated	31.8	27.4	3.4	9.3	2.4	4.1
Total industry	72.3	72.9	47.0	54.6	61.5	65.5
Academic, teaching primarily	0.2	0.9	4.1	3.5	15.7	15.2
Research primarily	1.1	2.2	2.9	3.2	7.2	5.5
Graduate study primarily	12.9	11.1	25.6	22.4	0.0	0.7
Research Institutes	2.5	1.6	2.9	3.2	0.0	6.2
Government	1.8	0.7	4.1	2.6	9.6	4.1
Military service	6.1	6.7	3.5	4.8	2.4	1.4
Other or unknown	3.1	3.9	9.9	5.7	3.6	1.4
Total number represented	556	804	172	313	83	145
% graduates represented	93.1	78.9	97.7	96.6	100.0	96.7

There was an increase over 1955-56 of nearly 10% in the totals for all three categories of degrees – Bachelors, Masters and Doctors. The number of Bachelors' degrees was 597, compared with 545 for 1955-56 – an increase of 9.5%. Masters' degrees totaled 176, compared with 163 for 1955-56 – an increase of 8%. Doctors were 83 versus 76 for the previous period – an increase of 9%. A breakdown of graduate degrees is shown in Fig. 1 in relation to data given in Dr. Bever's report for years back to 1948-49.

The totals for Bachelors' and Masters' degrees lie within the short-term trend ranges predicted by Mr. Bever from the 1955 returns, but the rate of increase in doctorate degrees appears to be slightly greater than he anticipated.

Foreign Students

There appears to be a rising trend in the number of foreign students being trained in metallurgy in the U.S. The number increased more than 30% last year compared with the previous year. The breakdown is as follows, where the figures in parentheses show 1955-56 foreign students:

Bachelors	Masters	Doctors
17 (13)	28 (19)	11 (10)

The number of foreign students returning to their home countries after receiving graduate degrees continues to represent about 10% of the degrees granted at the M.S. and Ph.D. levels. There is no indication that the training of foreign students is placing an undue burden on metallurgy departments.

Size of Classes

A study was made of size distribution for graduating classes. Only 11 out of 53 departments had graduating classes of more than 20 seniors last year, while 35 departments had graduating classes of ten or less. Graduate training, understandably so, is on an even more individual basis; classes of more than 10 M.S. or Ph.D. candidates are unusual.

Presumably many of the departments which have small classes of metallurgy majors are heavily engaged in teaching service courses in metallurgy to students majoring in other branches of engineering and science. Aside from a few of the larger departments, which may be operating close to capacity, and neglecting possible geographic factors or student preferences, it appears that American schools could handle a considerable increase in enrollment of metallurgical students without serious impact on the instructional load.

First Positions

The Table gives data on first positions taken by students after graduation. There are no major trends away from the composite picture for the two previous years (1954-56) with respect to first degree holders. There was a modest increase in the proportion of Masters' degree holders going into graduate study and teaching rather than to industry, and a less marked shift of Ph.D.s away from industry to academic research or government laboratories. Research institutes or foundations hired a smaller proportion of graduate degree holders last year than in the two preceding years, and Government agencies showed a substantial relative increase. Information reported on first positions taken was more complete for the 1956-57 period than for any of the previous years and approached a 100% sample.

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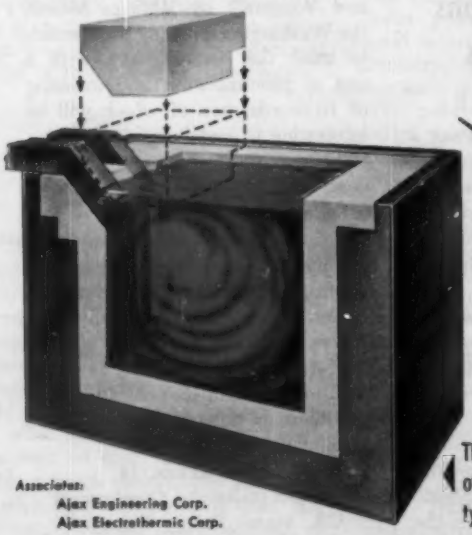

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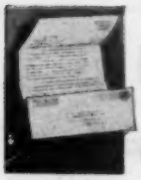

Correspondence

Temperature Uniformity

ROCKFORD, ILL.

The correspondence department in the August issue of *Metal Progress* carries a letter from Lindberg Engineering Co., signed by Cary G. Stevenson, objecting to certain portions of the subject matter of an article entitled "A Study of Temperature Uniformity in Heat Treating" published in the May issue.

Mr. Stevenson makes a point that is the exception rather than the rule in Ipsen furnaces, since the principle of 100% forced convection heating requires the shrouding of the control thermocouple from direct radiation in every way possible. This thermocouple is normally exposed only to the stream of heated atmosphere directed past the couple, and then through the furnace hearth, up and through the charge registered upon the hearth. Under these circumstances, with the static conditions described in the article and the shrouding of the thermocouple from direct radiation, the control temperature will lag any test point temperature in the charge that might be subjected to more exposure to edge heating effect. We believe that the fact is borne out by the curves published with the article, with which Mr. Stevenson apparently takes no issue.

In the case of a furnace equipment where the control thermocouple is directly exposed to the source of radiant heat, and would consequently indicate some intermediate temperature between the heat source and that of the cold charge, Mr. Stevenson's hypothesis is correct, but Ipsen engineers do not feel that $\pm 10^0$ uniformity throughout the chamber and charge of an Ipsen furnace would be possible where the control thermocouple is exposed to direct radiation.

We regret the use of the term "synchronous speed" with regard to the fan used in the test equipment. The intent was to indicate that there is direct drive to the fan, without any intermediate speed changes occasioned by pulleys and V-belts or similar expedient common to other manufacturers. The actual motor employed is a patented induction motor specially designed for low-speed starting in order to protect the fan on initial acceleration. After initial starting, the fan, which is directly connected and concentric with the motor shaft, is operated at rated motor speed, rather than "synchronous speed".

We trust that these explanations will clarify the intent of the statements in question.

W. F. Ross
Marketing Manager
Ipsen Industries, Inc.

Labeling Micrographs and Photographs

NEWPORT, R.I.

The usual methods for inserting a title or other wording on a picture require the services of both a photographer and layout personnel. Either a separate negative must be made from a print on which the line copy has been pasted, or a transparent negative which carries only the line copy must be prepared. The former method often leads to a loss of resolution when the print is photographed, and with the latter method the overlay negative can become separated from the picture negative. If the title is photographed as a part of the picture, the title must first be drawn or printed on a piece of cardboard.

As an alternative we suggest a fast, simple and inexpensive method. The desired text is typed on both sides of a polyethylene sheet approximately 0.003 in. thick, using reversed carbon papers. The polyethylene sheet is then inserted in the film holder between the unexposed film and the light source. Normal exposure gives a negative which also carries a title.

The method is especially useful for titling photographs of metallurgical specimens but it is applicable to other line copying operations as well.

H. PETER HIRSCHLER
VINCENT O. LAGERBERG
Research Division
U.S. Naval Underwater Ordnance Station

Words Are Funny Things

WASHINGTON, D. C.

In its department "Words, Wit and Wisdom", by William Morris, the Washington *Evening Star* recently tried the readers' wits with a test of pronunciation and meaning of 10 words, two of which will be interesting to metallurgists:

1. Anneal: *(a)* happening once a year; *(b)* strengthen and temper; *(c)* antagonize.

7. Antimony: *(a)* alimony paid to husbands; *(b)* small charitable offering; *(c)* silvery-white chemical.

Correct answers given by Mr. Morris are:

1. (b) uh-NEEL
7. (c) an-TIM-uh-nee

Almost as though the blind were leading the blind!

FRANK KERZE, JR.
Division of Reactor Development
U.S. Atomic Energy Commission

Chemical Prepaint Treatments for Metal Surfaces

What they do, the types available, how they are applied

By J. H. GEYER
Manager, Product Development Dept.,
AMCHEM PRODUCTS, INC.

Paint systems have been steadily improved in an effort to produce more decorative, easier-to-apply, and more corrosion-resistant films. The ability, however, of any paint film to perform its predetermined functions cannot be fully utilized without properly preparing the metal surface.

The prepaint preparation of the metal surface is therefore a highly important part of the system. Chemical prepaint treatments are designed to do four jobs and do them well. First, they remove organic soils, shop dirt, scale, and rust or corrosion products from the metal surface. Second, they provide surfaces that are completely compatible with subsequent paint films. Third, they produce a *tooth* that promotes good paint film adhesion. Fourth, they effectively prevent underpaint corrosion growth after any breakthrough in the paint film.

Basically, there are four types of chemical prepaint treatments. These are phosphoric acid, iron phosphate, zinc phosphate, and amorphous phosphate or chromate. Each is discussed briefly in the following paragraphs.

Phosphoric Acid

Perhaps the most widely used and certainly one of the most economical chemical prepaint treatments is the phosphoric acid cleaner combination materials. ACP Deoxidine® is such a material. It removes organic soils, rust, scale and contaminating elements from the metal surface. It also produces a light etch on steel, aluminum or zinc surfaces which considerably aids in increasing paint adhesion. It does not, however, form an actual coating on the metal surface. Any breakthrough in the subsequent paint film will permit underfilm corrosion to proceed. Grades of Deoxidine are available for application by brush or swab, hot and cold dip, or hot spray.

Iron Phosphate

Iron phosphating processes are extensively used in the chemical prepaint treatment of appliances such as water heater shells, ranges, washers, dryers and other *white lines*. These processes will produce excellent paint-bonding films on the metal and retard or prevent underpaint corrosion. Duridine,® ACP's iron phosphating process, is a combination organic soil cleaner and iron phosphate coating material. Both the cleaning and coating operations take place in the same bath. Duridine and other iron phosphates do not lend themselves to brush-on application, are primarily designed for spray type equipment of four or five stages. But several dip installations are successfully operating today by inclusion of an alkali precleaning stage.

Zinc Phosphate

ACP Granodine® is an example of this type of chemical prepaint treatment process, the type now being used to treat steel in the automotive industry, and predominantly specified for steel ordnance and military items. This process forms a coating which offers the ultimate in paint adhesion promotion and vastly augments the corrosion resistance of subsequent paint films. Zinc phosphate materials are extremely flexible as to method of application—can be applied by brush, dip or automatic spray equipment. In a typical dip or power spray system, the stages would be alkali clean, water rinse, zinc phosphate treatment, water rinse, and acidulated final rinse. If the metal has considerable areas of rust or scale, an acid pickle is advisable following the alkali cleaning stage.

On zinc surfaces, the zinc phosphates perform a rather unique function. They act as a barrier against chemical reaction between the applied paint film and the zinc surface. This effectively prevents blistering of the paint and early breakdown of the film. This is in addition, of course, to the improvement of paint adhesion and the retarding of underpaint corrosion. ACP Lithoform® is specially designed for use over zinc surfaces and finds wide application as a prepaint treatment for ornamental zinc die castings, refrigerator liners, and on most galvanized work requiring painted finishes.

Amorphous Phosphate and Chromate

These coatings are the films produced by the ACP Alodine processes and similar ones on aluminum surfaces. They have met with wide acceptance in the prepaint treatment of venetian blind strips, refrigerator liners, aluminum heat transfer units, aircraft sheet metal assemblies, and many other items fabricated from aluminum. The various coatings provide an excellent film for the promotion of paint adhesion and effectively prevent underfilm corrosion. As in the case of zinc, aluminum exhibits a tendency to chemically react with some paint systems. The Alodine processes develop a barrier film between the paint and the aluminum surfaces which prevents this reaction. The Alodines are extremely versatile materials that can be applied to aluminum surfaces by brush, hand spray, dipping, mechanical spraying, or roller coating equipment. Brush application is particularly well adapted to the processing of parts too large for simple dip systems or in manufacturing operations that do not warrant a tank setup. In dip, spray or roller coating application, the system usually consists of an alkaline preclean, a water rinse, the Alodine treatment, a water rinse, and an acidulated final rinse. Where the surface is heavily oxidized, a deoxidizer in the line is needed.

The major chemical prepaint treatments for metals have been covered briefly in this article. More complete information can be had by contacting an ACP sales representative or by writing us at Ambler, Pa.

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Personal Mention

William J. Hilty

In line with the growth and expansion of the *Metal Progress* sales staff, **William J. Hilty** has been promoted to the newly established post of Cleveland-Pittsburgh regional manager. His former position as Cleveland district manager will be filled by a newcomer to the Metal Progress staff, **Rodney W. Cramer**. Cramer was formerly with H. L. Stuart & Associates, Cleveland, general publishers' representative, before opening his own office in 1955.

A native of Ashland, Ohio, Hilty served as a bombardier-navigator in the Second World War and on his return to Cleveland in 1945, enrolled at Fenn College night school. After receiving his bachelor's degree in marketing in 1948, he joined Flxible Co. in Loudenville, Ohio, where he served as advertising manager. Three years later he became a staff member of the industrial advertising creative department of Fuller & Smith & Ross, Cleveland, and in 1955 came to *Metal Progress* as Cleveland district manager.

An active member of various advertising and marketing groups, he is currently chairman of the educational committee for the Cleveland Chapter of the National Industrial Advertisers Assoc. He was chairman of the Cleveland t.f. Club Awards Contest early this year, the largest advertising achievement contest in the country. In addition, he is currently enrolled in the Metals Engineering Institute.

Franklin Bruce Rote, technical director of Albion Malleable Iron Co., Albion, Michigan, received an Award of Scientific Merit from the American Foundrymen's Society "for noteworthy contributions to the AFS Malleable Divisions in furthering the technical prestige of the Society". The presentation was made at the Annual Business Meeting of the Society in May during the 62nd AFS Casting Congress and Show. Other awards given by the AFS at that time went to **Ralph A. Clark**, manager of foundry services, Electro Metallurgical Co., Cleveland, who was awarded the Pangborn Gold Medal "for outstanding contributions to the Society and the ferrous casting industry, especially in the field of gray iron metallurgy", and to **Howard J. Rowe**, chief metallurgist, castings division, Aluminum Co. of America, Pittsburgh, who received the McFadden Gold Metal "for outstanding contributions to the Society and to the light metals branch of the castings industry".

Richard Y. Moss was appointed manager of by-products and Lukenweld fabrication sales of the Lukens Steel Co., Coatesville, Pa. Prior to this, Mr. Moss was with E. W. Bliss Co. as manager of special products.

G. R. Semans, formerly assistant director of metallurgy at Jessop Steel Co., Pittsburgh, has been named director of metallurgy there. Mr. Semans joined Jessop in 1955 as assistant director of metallurgy. He is a member of the University of Pittsburgh faculty, teaching graduate school courses in stainless steel metallurgy and high-temperature metals. **C. M. Carlisle**, also of Jessop Steel Co., has been made director of analytical chemistry. Mr. Carlisle came to Jessop in 1956 and became chief chemist the same year.

John H. Gross, assistant professor in metallurgy at Lehigh University, has been granted a leave of absence for the 1958-59 academic year to permit him to accept a position on the research staff of the U. S. Steel Corp.

Grant A. Morrison, formerly engineering administrator, has been named manager of product design and application engineering at the metallurgical products department of General Electric Co., Detroit. A member of the General Electric staff since 1951, he was concerned with component and mining sales in Houston, Tex., before receiving his latest assignment.

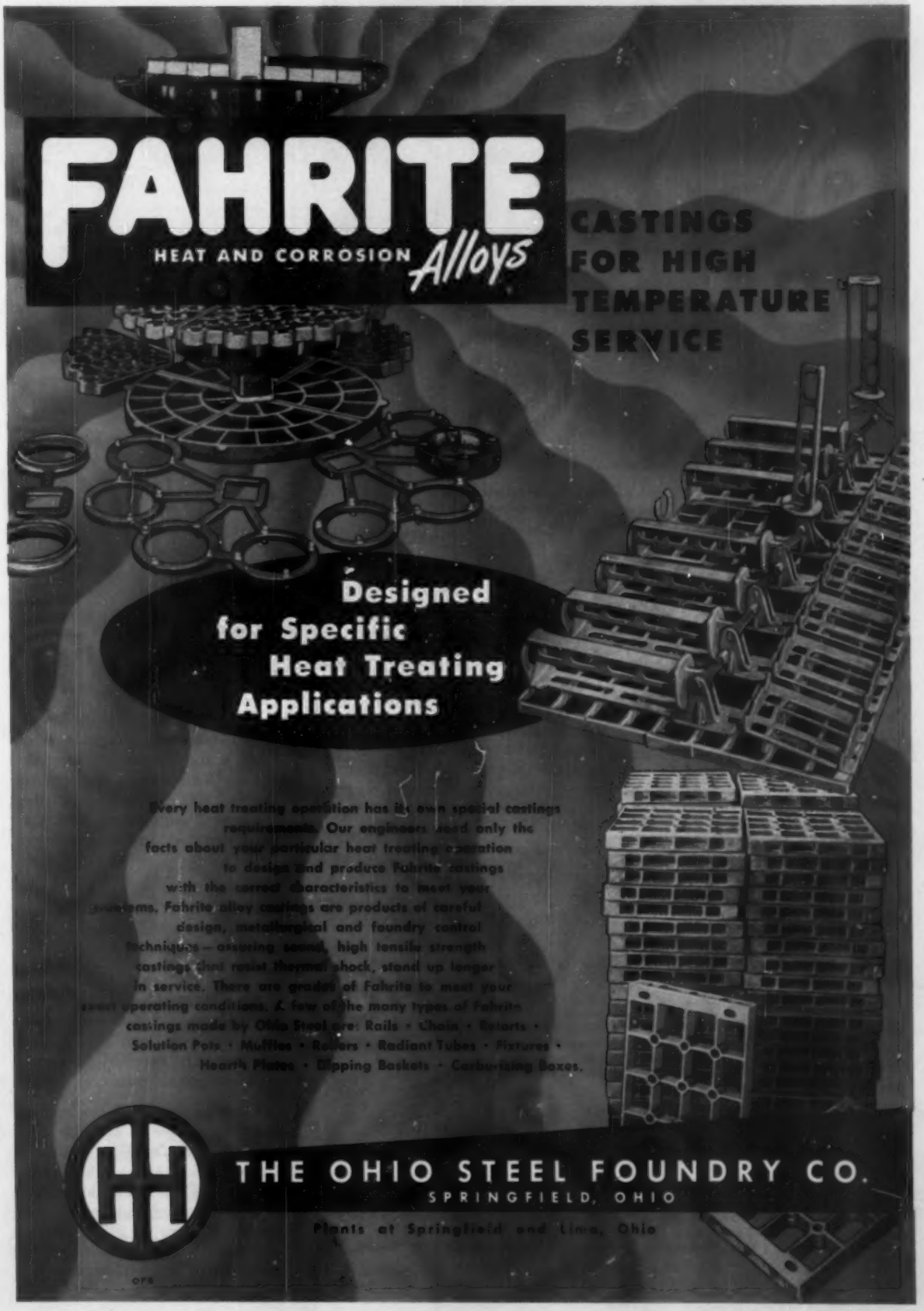
Hans Meyer has accepted a position with the engineering staff of Richard D. Brew & Co., Inc., Concord, N. H. Mr. Meyer was formerly with Epsco, Inc.

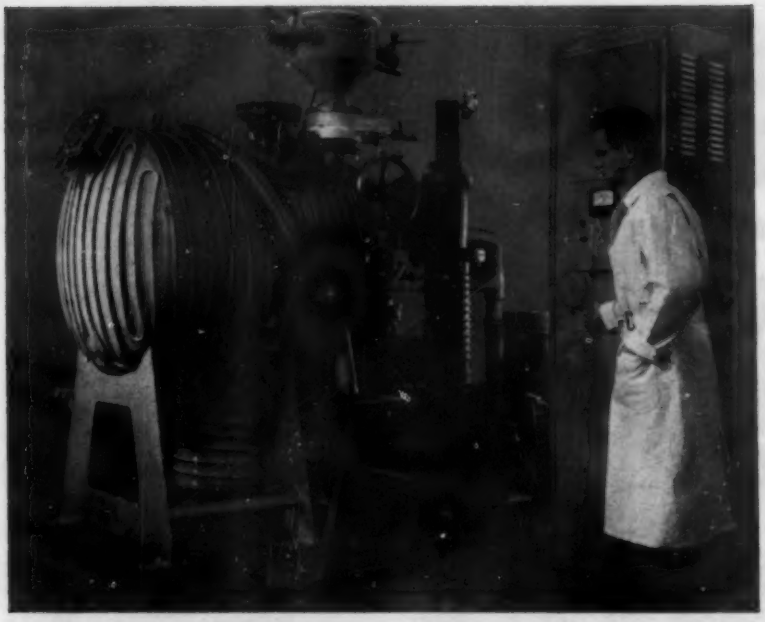
James K. McLaughlin has accepted the position of general sales manager of the Magnethermic Corp., Youngstown, Ohio. Mr. McLaughlin has been with Magnethermic Corp. since his graduation from Youngstown University in 1951. He had worked in both engineering and field service prior to entering the sales department in 1954. **Peter A. Hassell** has been appointed assistant general sales manager for the same company. Mr. Hassell has been in the induction heating industry for the last 17 years and joined Magnethermic Corp. in October 1954 as manager of the high-frequency division sales department. Both men maintain offices at the headquarters in Youngstown, Ohio.

Clarence Bremer, formerly director of research, has been appointed technical director of Oakite Products, Inc., New York, with responsibility for the company's research and product development, and technical service laboratories.

James H. Bly has been named assistant sales manager in charge of domestic sales at High Voltage Engineering Corp. Mr. Bly joined the company in 1956 to supervise sales and engineering activities related to application of high voltage X-ray generators in industrial radiography. Prior to joining the Burlington, Mass., firm, Bly was with X-Ray, Inc., Detroit.

John E. King has been appointed new sales manager for the J. W. Rex Co. in Lansdale, Pa. Mr. King was previously assistant to the manager in defense products with the Heintz Div. of Kelsey-Hayes Co. in Philadelphia.


FAHRITE
HEAT AND CORROSION Alloys
CASTINGS FOR HIGH TEMPERATURE SERVICE
Designed for Specific Heat Treating Applications
Every heat treating operation has its own special castings requirements. Our engineers need only the facts about your particular heat treating operation to design and produce Fahrite castings with the correct characteristics to meet your conditions. Fahrite alloy castings are products of careful design, metallurgical and foundry control techniques — assuring sound, high tensile strength castings that resist thermal shock, stand up longer in service. There are grades of Fahrite to meet your exact operating conditions. A few of the many types of Fahrite castings made by Ohio Steel are: Rails • Chain • Retorts • Solution Pots • Muffles • Rollers • Radiant Tubes • Fixtures • Hearth Plates • Dipping Baskets • Carburizing Boxes.
THE OHIO STEEL FOUNDRY CO.
SPRINGFIELD, OHIO
Plants at Springfield and Lima, Ohio



Process observation, alloy additions, pouring, temperature and process readings, high frequency control, valve sequencing—all focus around one center of operation.

For precision casting

a high-vacuum furnace for lab and pilot plant

CEC's 5 to 50 pound melting and casting furnace offers:

Three-way casting: Melts of 5, 12, 17, 30, or 50 pounds can be cast in single or multiple molds—or (with adaptation) centrifugally.

Ease of materials handling: All parts of the furnace interior are within arm's reach. The oblique angle flange connecting the stainless steel chamber sections provides unusual vertical clearance for removing molds directly. A deep water-cooled mold well provides 33" under the crucible lip for pouring bar-type ingots. Electric feedthroughs are provided for mold heating.

Complete controls: The basic furnace includes a manual bridge-breaker, a feeder and alloy cup mechanism, and a nonfogging sight tube for optical pyrometry. Pneumatic line valves are interlocked and controlled from central panel for safe, sure operation. It's easy to add a sampler, thermocouple, and equipment for semi-continuous operation.

Ample pumping: A 2-stage diffusion-ejector pump quickly brings the compact system to the low micron pressure range, with ample reserve capacity to handle gas loads generated by alloy additions, deoxidation, and pouring.

Write for illustrated Bulletin 4-30, which lists complete specifications, accessories, and design features of this remarkably versatile furnace.

Interior view of compact furnace shows alloy addition devices and crucible trunions.

Consolidated Electrodynamics

Rochester Division, Rochester 3, N. Y.

SALES AND SERVICE OFFICES IN PRINCIPAL CITIES

Personals . . .

William Bodine has assumed new duties as sales engineer for the new K S M Products, Inc., office in New Orleans, La.

William B. Jacobsen will be works manager of the Lemont Mfg. Corp., a new steel mill subsidiary being built by Ceco Steel Products Corp. near Lemont, Illinois. Mr. Jacobsen has held similar positions at Southwest Steel Rolling Mills, Oregon Steel Mills, Colorado Fuel and Iron Corp. and Creede Mills.

Douglass C. Johnston was recently appointed assistant secretary of the Metallurgical Society of A.I.M.E. Before accepting this appointment, Mr. Johnston had been employed by Bethlehem Steel Co., Bethlehem, Pa., and the Atlantic Refining Co. in Philadelphia.

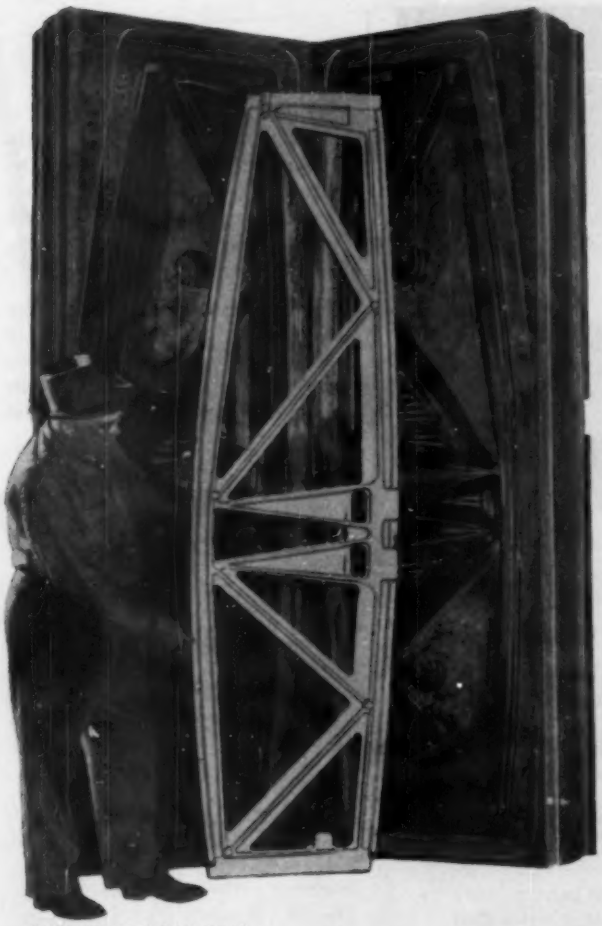
Gerald M. Henriksen has been elected as a director and vice-president of Acoustica Associates, Inc., Mineola, N. Y., and Culver City, Calif. Mr. Henriksen, who joined Acoustica recently, was formerly director of research and engineering, Turbo Div., American Machine and Foundry Co., Pacoima, Calif.

Robert C. Hiltbrand has assumed duties as manager of export sales of the Electric Furnace Co., Salem, Ohio. Joining the organization in 1938, he has served in their mechanical engineering, field erection, electrical and fuel divisions, and other departments.

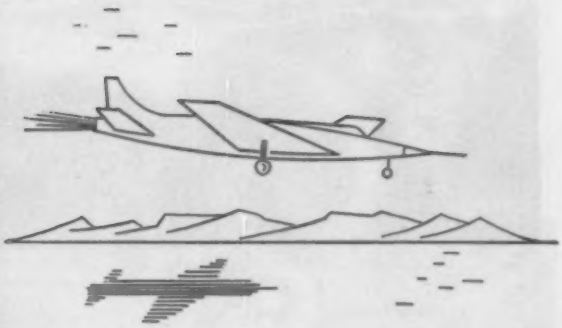
Charles Hays, formerly at the University of Kentucky, has recently been appointed to the staff of the Oak Ridge National Laboratory, Oak Ridge, Tenn.

Kenneth M. Gleszer has been elected president of Dixon Sintaloy, Inc., Stamford, Conn. Mr. Gleszer was formerly executive vice-president and general manager.

Victor G. Goodell has been appointed manager of Crucible Steel Co. of America's newly established Grand Rapids, Mich., sales branch. Mr. Goodell joined Crucible in 1952 as a sales trainee and became sales service engineer in 1953. He was appointed warehouse manager last year when Crucible opened a new location in Grand Rapids.



COURTESY ALUMINUM COMPANY OF AMERICA



Increase Production

with FINKL DIE BLOCKS

...the aircraft industry does!

These two 14 x 35 x 114" FX die blocks, made from Finkl electric furnace steel, and weighing 15,800 pounds each, are used for producing precision aluminum landing gear rib forgings.

Finkl FX die blocks are noted for their long production runs and economy because:

- FX covers the full usable hardness range from Temper H (477-444 BHN) to Temper 4 (293-269 BHN).
- FX produces the greatest number of forgings per impression because its well balanced alloy content offers uniform hardness and freedom from temper brittleness. Relatively high tempering temperature promotes ductility and elimination of residual stresses.
- FX Special Machining Quality appreciably reduces shanking and sinking time.

These proved advantages can also mean savings to you with more pieces per die and better deliveries to your customers.

Save money by talking to a Finkl representative the next time you are considering die blocks or forgings.

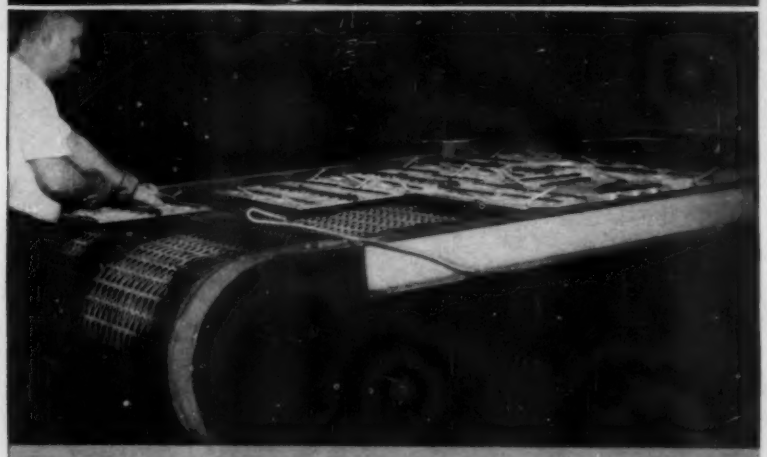
DIE BLOCKS · FORGINGS · HOT WORK STEELS · ELECTRIC FURNACE STEELS

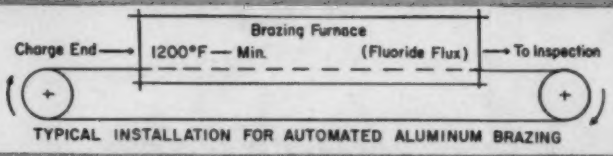
A. Finkl & Sons Co.

2011 SOUTHPORT AVE · CHICAGO 14, ILLINOIS

Offices in: DETROIT · CLEVELAND · PITTSBURGH · INDIANAPOLIS · HOUSTON · ALLENTOWN · ST. PAUL
COLORADO SPRINGS · SAN FRANCISCO · SEATTLE · BIRMINGHAM · KANSAS CITY
Warehouses in: CHICAGO · DETROIT · BOSTON · LOS ANGELES

Cambridge WOVEN WIRE BELTS





TYPICAL INSTALLATION FOR AUTOMATED ALUMINUM BRAZING

METAL-MESH BELT CONTROLS PRODUCT UNIFORMITY IN CONTINUOUS BRAZING

Here's a belt that not only shrugs off hot atmospheres and corrosive fluxes, but helps produce uniformly brazed parts continuously —and in less time. Moving through the furnace at a controlled speed, the all-metal Cambridge Belt allows the atmosphere to circulate freely through its open mesh and around the product for fast, thorough treatment.

In heat treating, cleaning or quenching operations, too, Cambridge Belts help maintain capacity production and cut operating costs. Here's how:

CONTINUOUSLY MOVING BELTS ELIMINATE BATCH PROCESSING—give faster, more economical production; reduce manual handling.

ALL-METAL CONSTRUCTION IS HEATPROOF, COLDPROOF, ACIDPROOF—Cambridge belts can be woven from any metal or alloy to take sub-zero or up to 2100° F. temperatures, yet remain impervious to corrosive atmospheres or solutions.

OPEN MESH PROVIDES FREE AIR, LIQUID CIRCULATION—gives more uniform processing of product; grit, sand, quench solutions drain through belt immediately.

SPECIAL SURFACE ATTACHMENTS AVAILABLE—raised edges or cross flights hold product on belt during movement.

Talk to your Cambridge Field Engineer soon—he'll explain the many advantages of continuous heat treating on Cambridge Woven Wire Belts. He'll recommend the belt size, mesh or weave—and the metal or alloy—best suited to your operations. You'll find his name in the classified phone book under "BELTING, MECHANICAL." Or, write for FREE 130-PAGE REFERENCE MANUAL giving mesh specifications, design information and metallurgical data.

The Cambridge Wire Cloth Co.

WIRE CLOTH | METAL-MESH CONVEYOR BELTS | WIRE CLOTH FABRICATIONS

Department B, Cambridge 9, Maryland

OFFICES IN PRINCIPAL INDUSTRIAL CITIES

Personals . . .

H. J. Huester is now located in the technical data division of the Bureau of Aeronautics, Navy Department, Washington, D. C., where he is engaged in military standardization of aeronautical materials, processes and procedures.

R. E. Fitzpatrick has been appointed district sales manager in Cleveland for the Fulton Sylphon Div. of Robertshaw-Fulton Controls Co. Mr. Fitzpatrick joined Fulton Sylphon in 1947.

Frank La Haye is currently head of the technical staff and director of technical sales for McCormick Selph Associates of Hollister, Calif. Mr. La Haye has been vice-president of the company for four years.

John H. Becque, formerly metallurgist for the Railway Wheel Assoc., Chicago, was transferred to Griffin Wheel Co., Chicago. His new position is research metallurgist in charge of gray iron and nonferrous research.

Frank J. Ross has accepted the position of manufacturing research engineer with the Missile Systems Div. of Lockheed Aircraft Corp., Sunnyvale, Calif.

James Hutchinson, recently released from the Army, has returned to the Irvin Works of the U. S. Steel Corp., where he has resumed his duties as metallurgical technologist in the metallurgy and inspection division.

W. F. Pravel has accepted the duties of supervisor of toolsteel application development at Allegheny Ludlum Steel Corp., Pittsburgh.

Peter J. Koros has completed the requirements for the Doctor of Science degree in the Dept. of Metallurgy at Massachusetts Institute of Technology and has joined the staff of the Graham Research Laboratory of Jones & Laughlin Steel Corp., Pittsburgh.

Kenneth E. Parr has left the Electro Metallurgical Co., Niagara Falls, N. Y., on a leave of absence to serve two years in the U. S. Army, and is presently attending the U. S. Army Ordnance Guided Missile School at Redstone Arsenal, Ala.

HOT STRIP MILLS

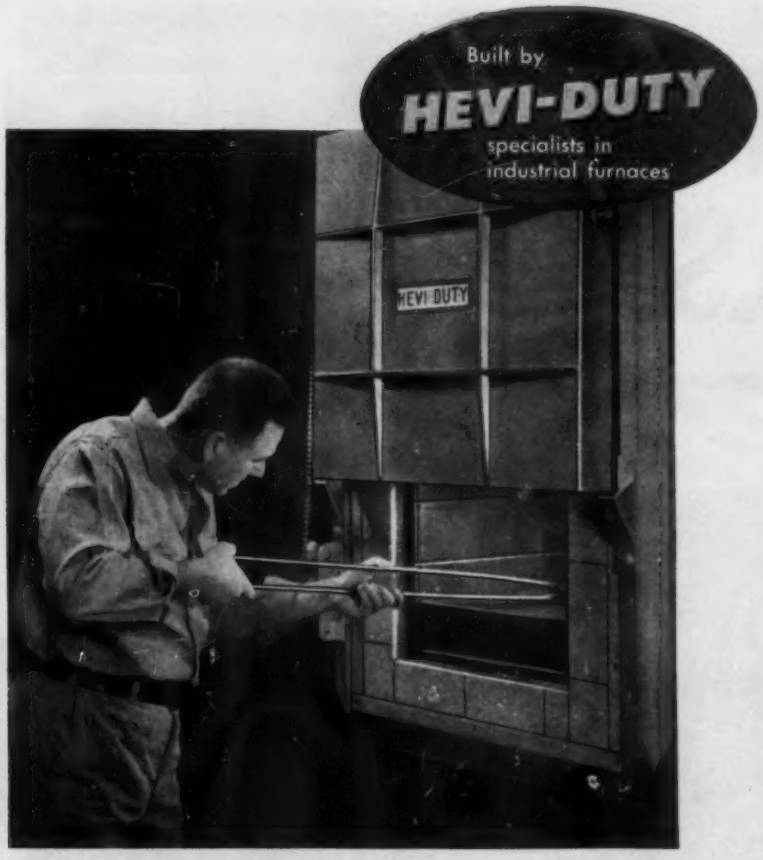
Designed and Built by MESTA

MESTA 56" Four-High Hot Strip Mill for Rolling Stainless, Silicon, High-Alloy and Carbon Steels at Allegheny Ludlum Steel Corporation

Designers and Builders of Complete Steel Plants

MESTA MACHINE COMPANY

PITTSBURGH, PENNSYLVANIA



Temperite® furnace keeps an eye on steel quality for Universal Cyclops

This Hevi-Duty Temperite furnace plays an important part in quality control at Universal Cyclops Company, Bridgeville, Pennsylvania. It is used in the laboratory for aging high-temperature alloys and for tempering tool steel.

Samples of plate, sheet and bar stock up to 24 inches long are selected at random from the mill production and spot-checked to make sure rigid specifications are met. High-temperature alloys are aged at 1325°F., and tool steels are tempered up to 1100°F.

R. D. Williams, the supervising metallurgist, says that the large capacity and excellent temperature uniformity of the Temperite furnace make possible extremely accurate tests of large batches of samples. He also appreciates the fact that it has required no servicing despite its being used 24 hours a day.

For further details on the Hevi-Duty Temperite furnace, write for Bulletin 355.

- Industrial Furnaces electric and fuel
- Dry Type Transformers
- Constant Current Regulators

HEVI-DUTY ELECTRIC CO.
Milwaukee 1, Wisconsin

Personals . . .

Charles A. Fox has been appointed Pittsburgh district sales manager of the Vulcan-Kidd Steel Div. of H. K. Porter Company, Inc., Aliquippa, Pa., with headquarters at the company's home office. Formerly a territory salesman in the Pittsburgh district, Mr. Fox started his career with Vulcan-Kidd in 1942.

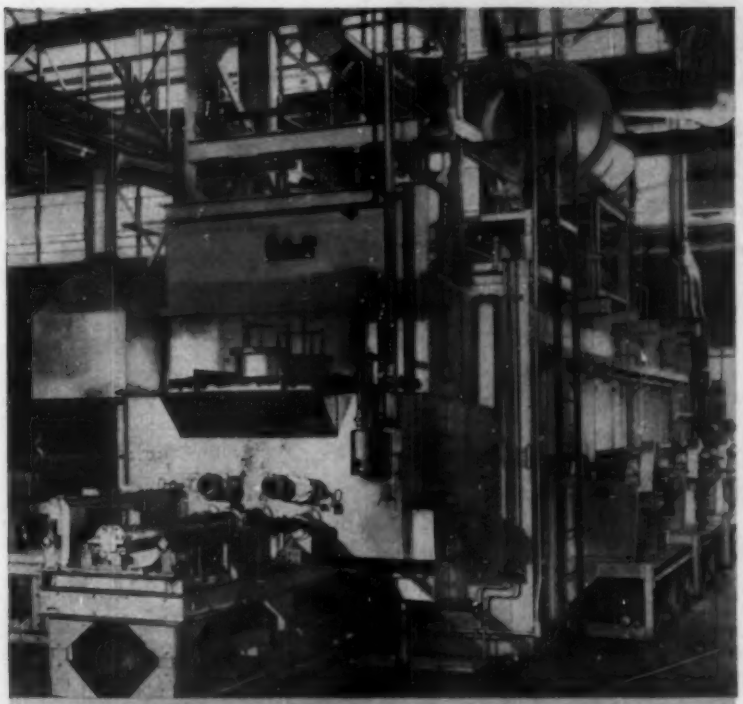
P. E. Fedeles has been appointed by Latrobe Steel Co., Latrobe, Pa., as sales engineer for the metalworking industry in Western Michigan. Mr. Fedeles has been a metallurgical engineer in the standards and inspection department at Latrobe Steel as well as a metallurgical engineer in the sales-service department.

Raymond F. Decker, who recently completed his graduate studies at the University of Michigan, has joined the research laboratory of the International Nickel Co., Inc., New York. Dr. Decker is now engaged in studies and development of nickel alloys.

Kuang Lu Cheng, formerly of Westinghouse Electric Co.'s materials engineering department in East Pittsburgh, has been appointed associate director of research, Utica Metals Div., Kelsey-Hayes Co. A native of Yangchow, China, Dr. Cheng came to the United States in 1947 and received his Ph.D. in analytical chemistry at the University of Illinois in 1951. Before joining Westinghouse, he taught for two years ago at the University of Connecticut.

Leslie H. Gillette, western regional sales manager for Magic Door sales, will become manager of industrial sales with headquarters in New Britain, Conn., for Stanley Hardware Div. of Stanley Works. Mr. Gillette came to Stanley from the industrial heating division of the Westinghouse Electric Corp., Meadville, Pa., where he was employed for 19 years. He was made divisional sales manager in 1948 and marketing manager in 1955.

John T. Clark, Jr. has been appointed head of the vitrified products section of the product engineering department of the Norton Co., Worcester, Mass.



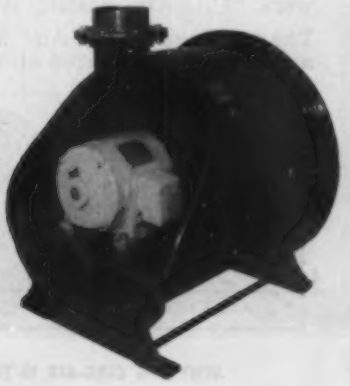
CONTINUOUS GAS CARBURIZER BY *INDUSTRIAL HEATING EQUIPMENT CO.* . . . EQUIPPED WITH SPENCER BLOWER

SPECIFICATIONS

FURNACE	BLOWER
TYPE: Continuous tray pusher.	TYPE: Spencer Centrifugal Turbo-Compressor.
CAPACITY: Up to 2000 lbs. per hour of light case carburizing.	AIR DELIVERY: 1150 CFM @ 20 oz. pressure.
TEMP. RANGE: 1550-1700° F.	MOTOR: 10 HP; 1,750 RPM.
FUEL: 3,800 CFH natural gas.	

On Critical Applications Like this . . .

reliable SPENCER blowers



Costly, critical automotive transmission parts processed in this carburizing furnace require absolutely dependable combustion air delivery.

That's why . . . here and in countless similar applications where cost must be competitive but where there can be no compromise with quality . . . you'll find SPENCER blowers.

Metals men know from experience that the superior features of Spencer Turbo-Compressors—simplicity of design, wide clearances, all metal construction, uniform pressure under varying load conditions—are their assurance of *continuous* satisfactory performance.

Whatever *your* need in blowers—from ⅓ to 1,000 HP, volumes up to 20,000 CFM, pressures from 4 oz. to 10 lbs., it will pay to check with Spencer.

Request Catalog 126-A containing complete specifications.

SPENCER HARTFORD

The SPENCER TURBINE COMPANY

Continuous CIRC-AIR Tempering

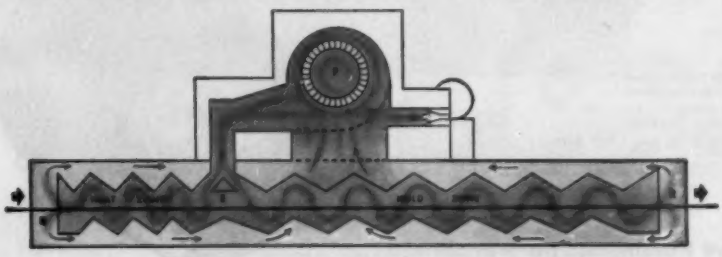
AT ± 5° F.

Industrial's "Circ-Air" tempering furnace is the most efficient heating machine ever designed.

The turbulent recirculation of hot gases through and around the work insures maximum and uniform heat transfer. Proper channeling of the hot gases to the work prevents wasteful dissipation of heat; and puts heat where it is needed — on the work.

A "Circ-Air" processing 2000 lbs. per hour at 1300° F., holding ±5° F., forces 14,500 C. F. M. of hot gases through the work. "Circ-Air" heating is recirculation at its best.

The continuous "Circ-Air" is suitable for heating steel, brass, aluminum and cast iron at temperatures up to 1450° F.



WHY THE CIRC-AIR IS THE BEST TEMPERING FURNACE!

The work is carried on a continuous conveyor. Loading can vary; ¼" bolts are densely loaded up to 3" deep. Less dense loading may be 20" deep. A 3' x 21' "Circ-Air" tempers over 2000 lbs. per hour.

Hot gases from the combustion chamber "C" and recirculated gases returning from the work chamber mix in the fan area "F." Entering the heating area through "T" at control temperature, balanced heat is directed to the charge and discharge ends, and is returned to the mixing chamber. The continuous V construction of the metal liner forces the hot gases up and down through the load at high velocity. The hot gases in the heating zone flow counter to the work. Heat transfer is rapid. Equilibrium is reached at point "E", and ±5° F. is held the length of the holding zone. Heating is without temperature head.

"Circ-Air" furnaces have been built in widths up to 108 inches, in lengths up to 165 feet, for temperatures from 250 to 1450° F., and capacities from 200 to 16,000 lbs. per hour. *Send for Bulletin 13-A*

INDUSTRIAL
HEATING EQUIPMENT CO.

CIRC-AIR 3570 FREMONT PLACE, DETROIT 7, MICHIGAN • WALNUT 3-7000

PIONEERS AND STILL LEADERS IN RECIRCULATION

Personals . . .

Adolph Edward Palty has been appointed supervisor, alloy development and evaluation, of the Utica Metals Div., Kelsey-Hayes Co., Utica, N. Y. Dr. Palty came to Utica Metals from the Thomson Laboratory of General Electric Co., Lynn, Mass., where he served as a technical engineer in physical and mechanical metallurgy as applied to problems in the aircraft field.

Gustaf Peterson recently retired from his position as consulting metallurgist with the Edgcomb Steel Co., Philadelphia. He joined Edgcomb 24 years ago as manager of the toolsteel department, serving in this capacity until he was named consulting editor eight years ago.

Carl W. Lindahl has been assigned to the position of works manager of the Denison Engineering Div., American Brake Shoe Co., Columbus, Ohio. He will be in charge of all Denison manufacturing activities at the Columbus plant.

Earl L. Casey has been appointed manager of division services of the Texas Instruments, Inc., apparatus division. Mr. Casey was formerly general superintendent of manufacturing for the division.

Lloyd E. Raymond has been added to the staff of the Singer Mfg. Co., New York, as a senior process engineer. Formerly manager of the hardening and japanning departments at Singer's Bridgeport, Conn., factory, Mr. Raymond will investigate new processes and developments in the field of investment casting, powder metallurgy and hard surface coatings.

Walter E. Remmers, vice-president of the Union Carbide Corp., has been selected as the 1958 Charles Edgar Hoyt Memorial Lecturer for the American Foundrymen's Society. His lecture will be on "Silicon – Present and Future".

Marcus Evans has been named to the new post of vice-president for alloys, Tennessee Products & Chemical Corp., Nashville, Tenn. He first joined Tennessee Products and Chemical in 1956 to serve as works manager for the company's new electric furnace ferro-alloys plant at Rockwood, Tenn.

It used to take 40 man hours—

now 8 man hours do the job

Prior to delivery of RB-66 type jets and some military turbojet transports, Douglas makes a thorough check to see that no tools or loose items have been left that might cause structural damage. This means inspection of control surfaces and other areas difficult to "get at"—a job that took 40 man-hours even for the relatively small RB-66's.

Now, using Kodak Industrial X-ray Film, Type AA, and a Douglas-designed mobile x-ray unit, the work is cut to 8 man-hours.

This faster film permits areas of as much as 10 sq. ft. to be inspected with one exposure—with the x-ray tube as much as 15 ft. from the surface—and with "quartered" exposure time.

Easy to see how Kodak Industrial X-ray Film, Type AA, can save time and speed up routine examinations. It also extends the service of present radiographic equipment and produces quality results.

Have your Kodak x-ray dealer or Kodak Technical Representative show you what this film can do to lower costs, speed your operations.

EASTMAN KODAK COMPANY, *X-ray Division*, Rochester 4, N. Y.

Read what the new Kodak Industrial X-ray Film, Type AA, does for you:

- Reduces exposure time—speeds up routine examinations.
- Provides increased radiographic sensitivity through higher densities with established exposure and processing technics.
- Gives greater subject contrast, more detail and easier readability when established exposure times are used with reduced kilovoltage.
- Shortens processing cycle with existing exposure technics.
- Reduces the possibility of pressure desensitization under the usual shop conditions of use.

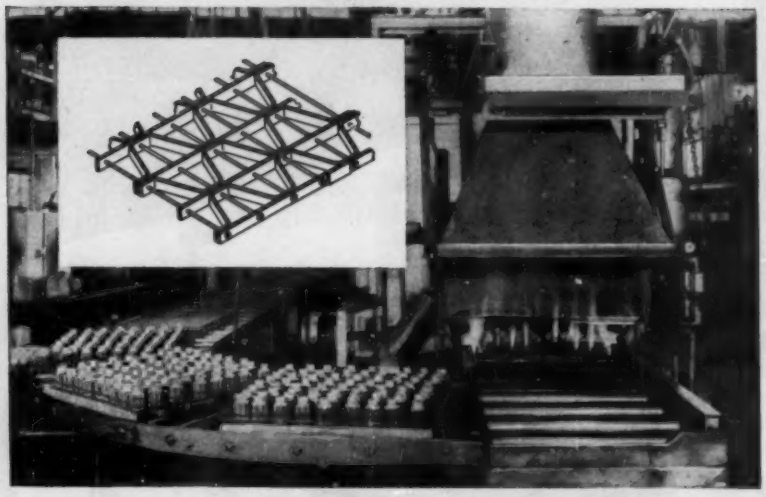
Kodak

ROLOCK

SPECIALIZED WELDED FABRICATIONS

HEAT AND CORROSION RESISTANT

Tray weight cut 40%...
Tray LIFE DOUBLED...



when rugged "SERPENTINES"
serve this HOLCROFT Furnace

This is just one more example of the remarkable cost-efficiency of Rolock "SERPENTINE" furnace trays... used here in a Holcroft, but standardized for all popular automatic furnaces with roller hearth.

The operation is sintering of powdered metal parts at 2050° F. in controlled atmosphere. Previous trays were "barn roof" channel type of 35-15 alloy and weighed 34 lbs. Life expectancy was less than a year, and sagging of the wire mesh supporting parts was always a problem.

Rolock "Serpentines," of which there are now 400 in the system on four furnaces, are of Inconel and weigh only 20 lbs. Life has averaged one and one-half to two years. Mesh and parts remain adequately supported.

Rolock engineers developed the unique "Serpentine" construction especially to meet such conditions as these. Again and again it has demonstrated exceptional economies. The design is standardized and trays are promptly available. Write us.

SALES AND SERVICE REPRESENTATIVES FROM COAST TO COAST

ROLOCK, INC., 1222 KINGS HIGHWAY, FAIRFIELD, CONN.

JOB-ENGINEERED for better work
Easier Operation, Lower Cost

7RLSB

Personals . . .

Edward J. Myers has accepted the position of metallurgy instructor at the Air Force Institute of Technology, Wright-Patterson Air Force Base, Ohio.

Charles R. Chambers has formed the Vacuum Furnace Div. of Richard D. Brew & Co., Inc., Concord, N. H., with R. D. Brew. Mr. Chambers now holds the position of general manager of the newly formed division.

Waller Bonsack has accepted a position as consultant and chief metallurgist with Aluminum and Magnesium, Inc., of Sandusky, Ohio, after five years of free-lance consulting work in the Los Angeles area.

Rudolph Ostermueller has become president and owner of Watson Metal Products Corp. located in Union City, N. J.

Bruce M. Shields, formerly assistant chief metallurgist, Duquesne Works, U. S. Steel Corp., Pittsburgh, has been promoted successively to assistant to the general superintendent and to chief metallurgist of the Duquesne Works.

Frank B. Gabranski has accepted a new position as project engineer, nuclear power plants, with Westinghouse Electric Corp.

William M. Pardue has reported to the U. S. Army Ordnance School, Aberdeen, Md., for a six-months tour of duty.

Paul A. Kinslow recently assumed the position of chief metallurgist of the Gary Works of Taylor Forge & Pipe Works, Chicago.

H. A. Blair now holds the title of plant engineer of the Cooper Alloy Corp., Hillside, N. J. Mr. Blair joined Cooper Alloy in 1957 as chief production engineer of the aircraft products division.

Harley C. Lee, vice-president and director of Basic, Inc., Cleveland, was awarded the Benjamin G. Lamme Medal of Ohio State University, one of that institution's highest honors. The medal is awarded yearly to an alumnus of Ohio State in recognition of "meritorious achievement in engineering or the technical arts".

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Personals . . .

Bernard Kopelman has been assigned director of market development for Sylvania-Corning Nuclear Corp., Bayside, N. Y. Prior to the formation of Sylcor in 1957, he was chief engineer of the atomic energy division of Sylvania Electric Products Inc.

Salvatore Maiorino is now employed as supplier contact in the purchasing department of the Rocketdyne Div., North American Aviation, Inc., Canoga Park, Calif. Until recently he was employed by Rayson Casting & Mfg., Gardena, Calif., as salesman and consultant.

C. W. Bertschi, formerly affiliated with Minneapolis-Honeywell Regulator Co., Minneapolis, Minn., is now at the Locomotive Finished Material Co. in Atchison, Kan.

Bichara B. Muvdi has joined the mechanical engineering faculty of Michigan College of Mining and Technology as assistant professor.

Donald P. Hoover has joined the staff of Pacific Scientific Co., Los Angeles, after ten years with Westinghouse Electric Corp. For the past year, he was responsible for the Pacific branch of Westinghouse's Industrial Heating Div.

Arthur L. Stowe has been assigned as sales and service engineer in the Springfield district office and warehouse of Vanadium-Alloys Steel Co., Latrobe, Pa. He had been plant metallurgist for Massachusetts Steel Treating Corp. since 1950.

W. H. Thomas of the Pittsburgh Coke & Chemical Co., has been promoted to general superintendent. Prior to his promotion, he was manager of maintenance and central engineering for the company.

Daniel F. Toner, recently separated from military service, has been appointed to the staff of the Oak Ridge National Laboratory, Oak Ridge, Tenn.

Raymond E. Wright has been appointed district industrial heating specialist for the General Electric Co. Apparatus Sales Div. central district. Prior to this appointment, he was district industrial heating specialist in Cincinnati for G. E.

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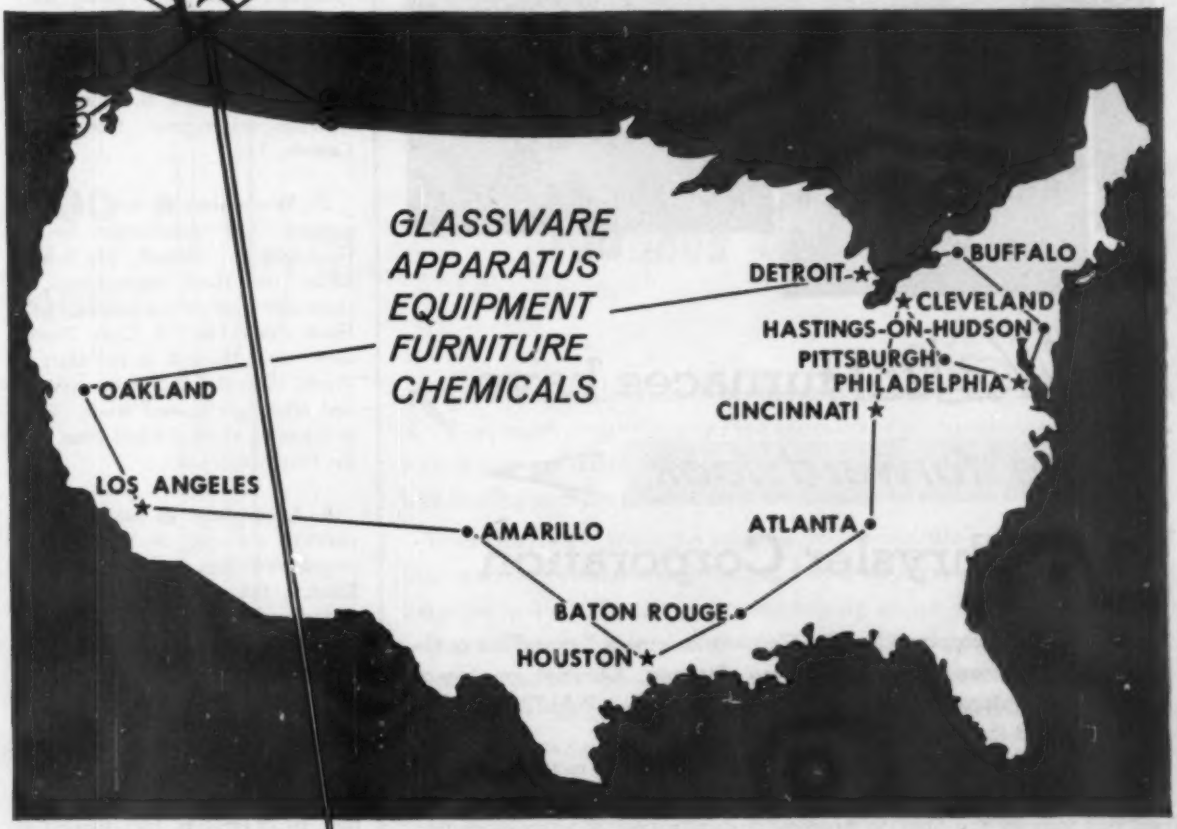

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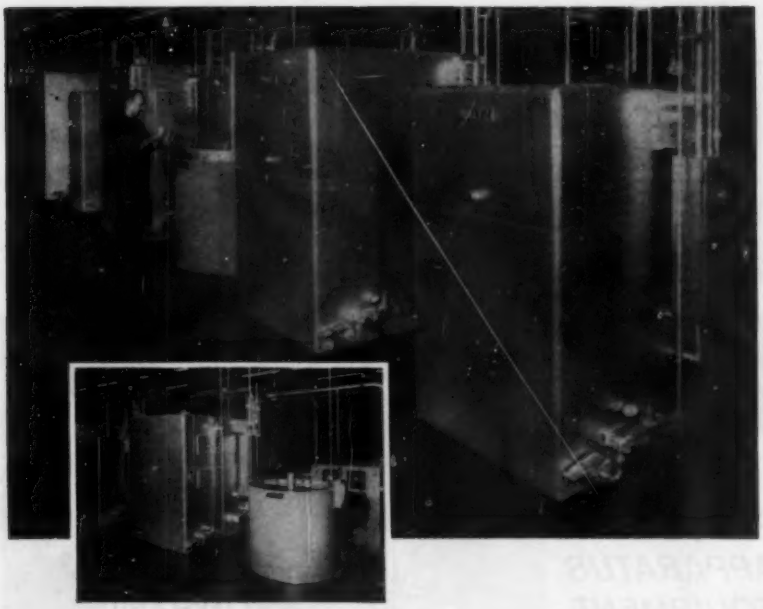

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Personals . . .

J. L. McCloud, formerly manager of manufacturing research of the staff manufacturing engineering office of the Ford Motor Co. and until his recent death a consulting editor of *Metal Progress*, was presented with a certificate of election to Honorary Membership in the American Society for Testing Materials during the 61st Annual Meeting of the Society in Boston. Also presented with an Honorary Membership was **James G. Morrow**, metallurgical engineer, Steel Co. of Canada, Ltd.

E. W. Schoen has been appointed chief metallurgist by the Huck Mfg. Co., Detroit. Mr. Schoen joined the Huck organization 20 years ago when it was known as the Huck Rivet Div. of Clark Equipment Co. He left at the start of World War II for defense contract and other government work. Prior to rejoining Huck, he had been with the Ford Motor Co.

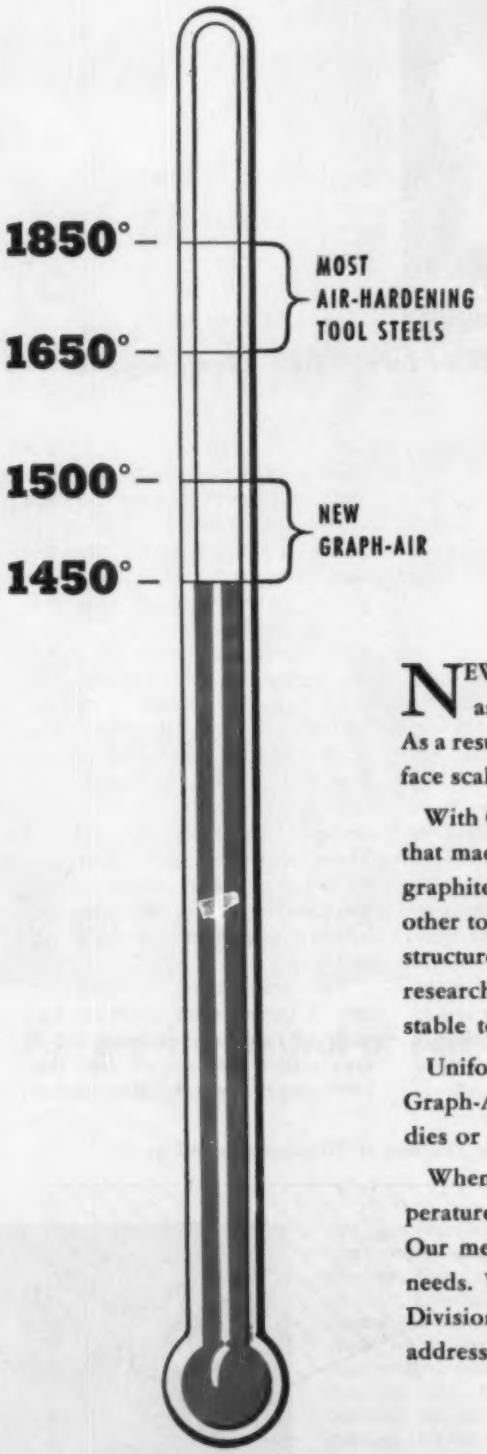
E. L. Layland has been appointed manager of metallurgical engineering for the Westinghouse Electric Co. materials engineering department in East Pittsburgh. Mr. Layland was formerly manager of the metallurgical application section of that department.

Walter Lojewski has accepted the position of vice-president of the newly formed steel treating corporation, Heat Treaters, Inc., located at Oriskany, N. Y.

Maurice J. Sinnott was appointed for a one-year term on the executive committee of the newly formed University of Michigan Research Institute and Willow Run Laboratories, Ann Arbor, Mich.

T. W. Ruffle has left the E. N. V. Engineering Co. Ltd., London, England. After a visit to the United States, he will set up a British office for Ipsen Industries, Inc., of Rockford, Illinois.

S. T. Jazwinski, director of research at the Phoenix Iron & Steel Co., received a Doctor of Science degree from Krakow Academy of Mining and Metallurgy in May.



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New Titanium Alloys

Digest of "Titanium Alloys for Air and Spacecraft", by Walter L. Finlay, M. B. Vordahl and R. F. Malone. Paper presented at a Technical Forum, Crucible Steel Co. of America, Pittsburgh, June 26, 1958.

TITANIUM, as a structural material, began to find its place in the sun at the beginning of the Korean War. It was used to quite an extent in the Century series of fighters and the B-52 bomber; then, suddenly, the 1957 economy wave and the growing transition from aircraft to missiles shot titanium's prospects down about as fast as they had previously risen. The titanium industry thus was faced with the challenge to lower its prices and improve its properties to comply with new sets of requirements established for advanced air and spacecraft.

Recently the price of unalloyed A-55 sheet was reduced from $10.60 to $9.60 per lb. and the price of A-55 billet was lowered from $6.20 to $4.30 per lb. Moreover, a new titanium sheet alloy was unveiled recently, Crucible's B 120 VCA (13 V, 11 Cr, 4 Al), having minimum yield strengths up to 220,000 psi. – just double the highest strength sheet alloy of five years ago.

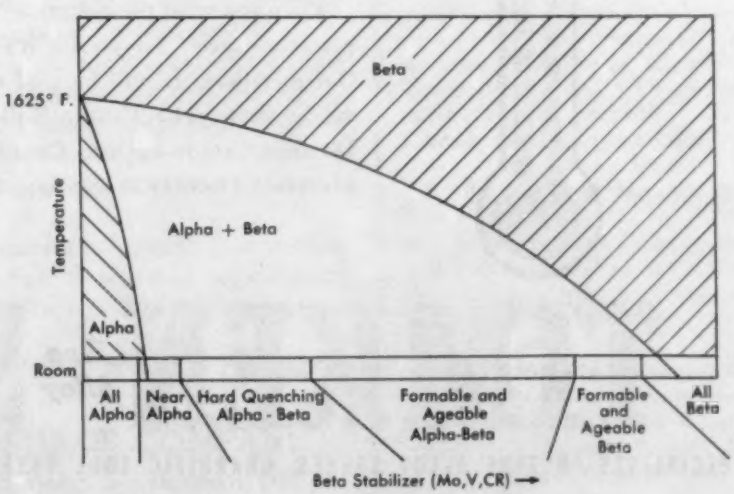
No One "Best" Metal – Air and spacecraft are rather complex vehicles with correspondingly sophisticated designs and what may be a best combination of properties for one application may be far from best in another.

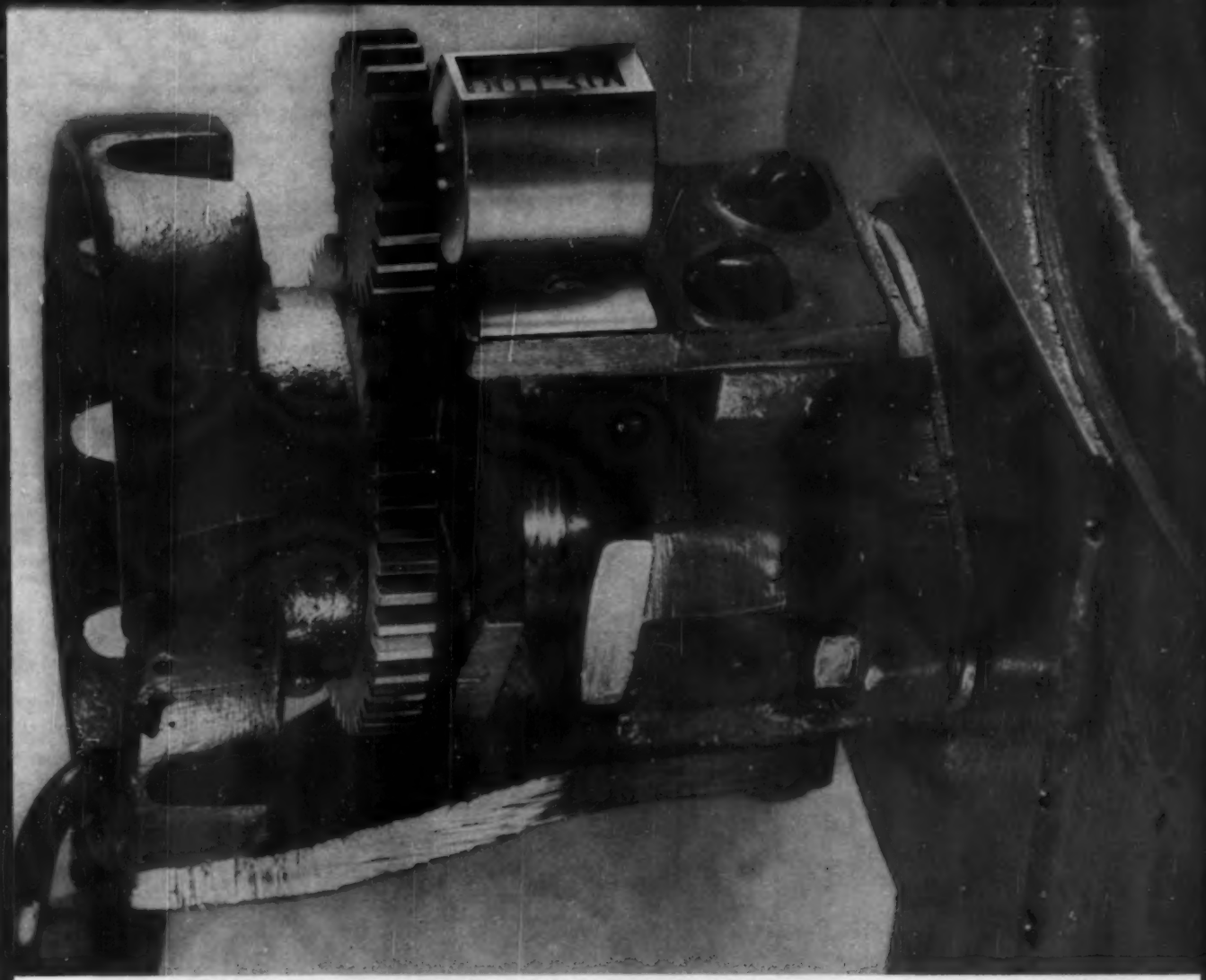
To consider some oversimplified examples as illustrations: If one needed the highest stiffness and lowest weight, beryllium might be the choice; if the best combination of room-temperature strength-weight, corrosion resistance, economy, and availability of very wide, long, thin, flat sheets and plates were required, aluminum might be the choice; if highest strength-weight for long times up to 800° F. and for short times up to about 1100° F. were essential, the new Department of Defense (DOD) titanium sheet alloys described later might be selected. For longer times in the 800 to 1100° F. range, the precipitation hardening stainless might be preferred, and at still higher temperatures Inconel X, the superalloys and finally molybdenum and the super refractory alloys would come into their own. Thus all advanced air and spacecraft are made from many materials because no single material meets all structural needs.

An earlier *Metal Progress* article ("The ABC of Titanium Alloys", November 1952, p. 873) listed three major categories of titanium alloys: (*a*) alpha (h.c.p.), (*b*) beta (b.c.c.), and (*c*) combined alpha and beta crystal structures. Each of these classifications connotes a particular combination of properties that often tells more about the general properties of the alloy than does its specific chemistry. Thus, alpha has all-around strength, stability, toughness and weldability but not the best formability; beta has best strength and fabricability but not the best long-time, high-temperature stability; and combined alpha-beta gives the best compromise strength, formability and stability. These three categories can be viewed as a more or less continuous spectrum of gradually changing combinations of properties as illustrated in Fig. 1.

The latter figure is schematic, since it ignores such significant features as eutectoid reactions, but it does reflect the over-all fact that increasing the beta stabilizer content

Fig. 1–Schematic Diagram of Titanium-Base Alloys





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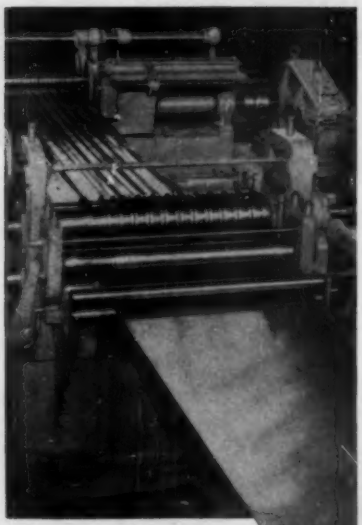

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Titanium Alloys . . .

of the alloy lowers the beta transus temperature until finally it is effectively below room temperature. Fitting into this spectrum is an important transition sequence of properties ranging from all-alpha's non heat treatability to the formable-soft, ageable-strong beta alloys, of which a current example is B 120 VCA. The alloy B 120 VCA, like its counterpart 18-8 stainless steel, has more than one quarter of its content as alloying elements. Thus, it has a strong solid-solution base and great strengthening potential.

As emphasized in the introduction, however, B 120 VCA is no cure-all for all materials of construction problems. For service up to 1000 hr. at 800 to 900° F., the alpha-beta DOD alloys are indicated. For heat treatable forgings for service up to 900 and 1000° F., C 135 AMo (7 Al, 4 Mo) is suggested for present and immediate future application. For future forgings operating at 900 to 1100° F., perhaps an all-alpha like RC 900 (12 Zr, 4 Al) or a near-alpha will be best. In such matchings of properties with service requirements, one of the more convenient and most commonly used bases for comparison of alternative materials of construction is the strength-weight ratio.

Strength-weight as a function of temperature is the universal initial criterion. Two strength criteria are of major importance: ultimate tensile and compressive yield. As Jackson has pointed out (Battelle Titanium Metallurgical Laboratory Report No. 5), 20 to 40% of the metal employed in a typical high-performance plane uses the ratio ultimate tensile strength to density as a basic design parameter. The DOD titanium sheet alloys and B 120 VCA have the highest strength-weight ratios under these design parameters.

Yield and creep strengths are also important criteria. Comparative values of these are shown in Fig. 2. These data were taken from Battelle's TML Report No. 91 on the "Status of High-Strength Steels for the Aircraft Industry", dated Jan. 3, 1958, for the latest available and reliable data on the steels and from Crucible data for the DOD alloys and B 120 VCA. The curves are drawn at strength levels having 5% minimum elongation associated with them. Thus the precipatation hardening steels at 220,000 psi. yield, the DOD alloys at 160,000 psi. yield and B 120 VCA at 190,000 psi. yield are compared with each other. On

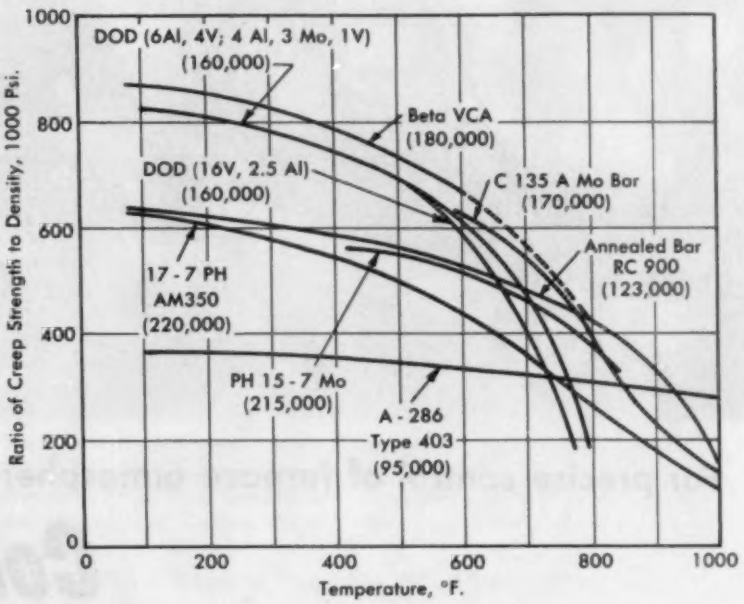

Fig. 2—Strength-Weight Comparison. Plastic Creep 0.2% in 500 hr. Figures in parentheses are 0.2% yield strength

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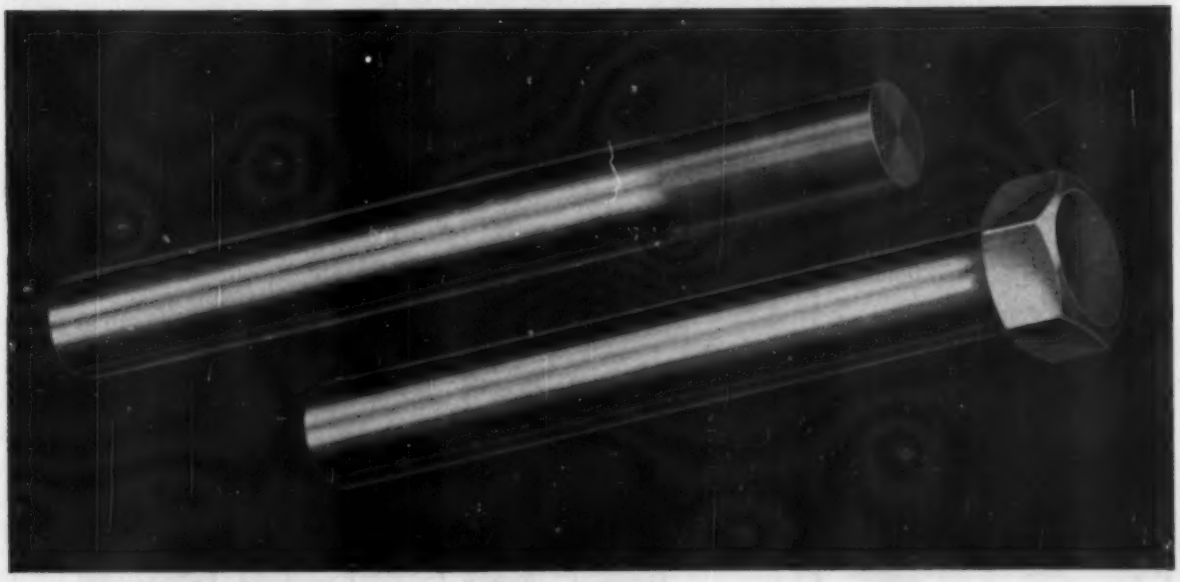

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Titanium Alloys . . .

both the 5% elongation and 2% elongation comparison bases, B 120 VCA compares very favorably with other structural materials.

Figure 2 shows the effects of time on comparative properties. For the particular longer time selected, 500 hr., the DOD titanium alloys and B 120 VCA are seen to maintain superiority up to at least 600° F. but the PH steels rapidly close the gap the higher the temperature. At about 700° F. the PH steels overtake the DOD alloys over the 500 hr. period being compared in Fig. 2. Figure 2 also illustrates another fine detail, namely the lower creep strength of one DOD alloy, 16 V, 2.5 Al, relative to two others, 6 Al, 4 V and 4 Al, 3 Mo, 1V, as shown by the sharper fall-off of 16 V, 2.5 Al in Fig. 2. This reflects the creep-strengthening contribution of increasing aluminum in these alloys.

To compete with the precipitation hardening steels for longer times at higher temperatures, the titanium industry offers high-aluminum alpha-betas like heat treated C 135 AMo which competes up to about 800° F., and near-alphas and alphas like RC 900 which compete successfully up to about 1000° F. at which temperature the superalloys like A 286, seen as the very flat curves in Fig. 2, take over.

However, if one wanted both high strength-weight at room temperatures plus highest strength-weight at 1000° F., RC 900 would give better strength-weight performance over the entire temperature range than A 286.

But above about 1000° F., present and immediately available titanium-base alloys do not appear to have useful strength where any appreciable times are involved. Where seconds or perhaps up to 1 min. only are involved as in some missiles, B 120 VCA may have structural utility up to perhaps 1400 or 1500° F.

After the simple strength-weight ratios, the next criterion is the structural indexes which have been developed to predict the failing load of typical structural sections in compression. Considerable advances have recently been made in this field. These have been particularly timely since the elevated-temperature performance of airframe and missile materials is a relatively new and unexplored subject.

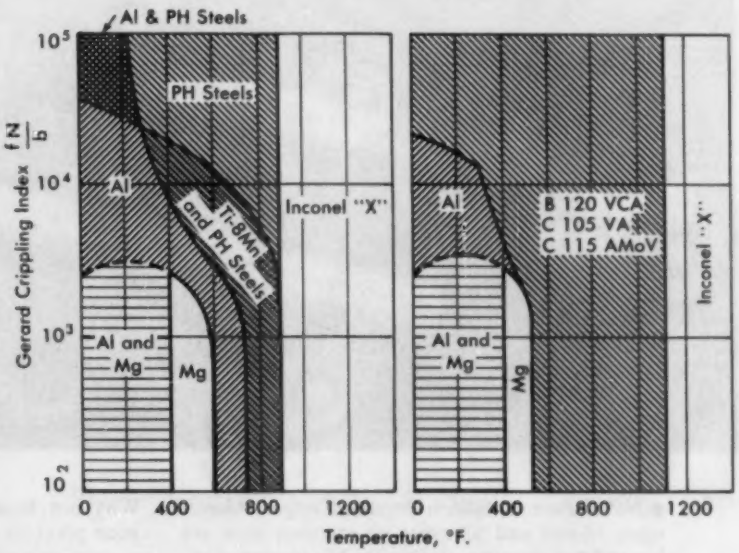
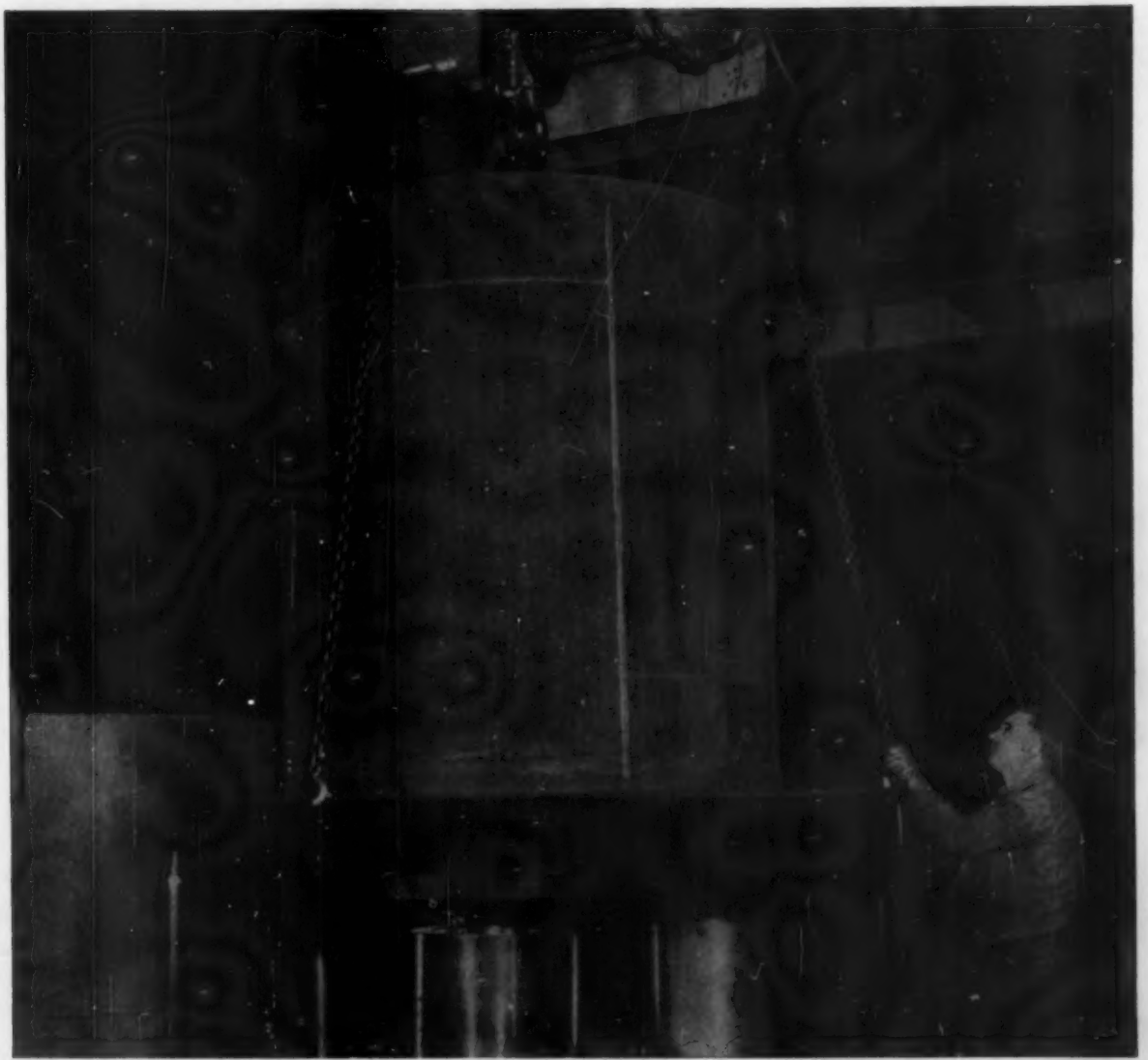


Fig. 3 — Crippling Strength of Compressive Elements. The newer titanium alloys are included in graph at right

Crippling Strength — Up to 90% of some air and spaceframes are designed for compression. Comparing candidate materials for compressive strength-weight as a function of temperature are therefore



Incoloy annealing hood raised above coils of Monel* nickel-copper alloy strip, at Plume and Atwood plant, Thomaston, Conn. Hoods made by Rolock, Inc., Fairfield, Conn.

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For 5000 hours, this Incoloy* nickel-iron-chromium alloy annealing hood has withstood 1200-1450°F service temperatures.

Notice there's no scaling or warping. No cracking either, even though it regularly goes through the severe thermal shock of spray quenching. It's as good as the day it left the fabricator's shop.

Plume and Atwood, producers of quality coiled strip of copper, brass, Monel and other alloys, have 8 of these Incoloy hoods. All are in excellent condition and in constant use.

You can expect this kind of service from other wrought Incoloy equipment such as retorts and thermocouple tubes. The reason... high strength and corrosion resistance at elevated temperatures.

With a growing reputation for economical performance in heat-treating applications up to 1800°F; with easy forming, and good welding properties; with relatively low initial cost; Incoloy equipment may well be just right for your operations.

For quotations on Incoloy equipment, ask your fabricator. For further information on these Incoloy alloy annealing hoods – ask Rolock, Inc., Fairfield, Conn. *Registered trademark

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Titanium Alloys . . .

very important. Merely comparing compression yield strengths is not adequate, however, since the compressive loads typically are supported by sheet stiffeners bent into L, Z and similar sections.

Titanium alloys are depicted as generally superior to the other airframe materials. The 6 Al, 4 V material involved in tests had an ultimate tensile strength at the 180,000 psi. level; but the heat treated 6 Al, 4 V curve may be considered that of any titanium-base alloy such as the DOD alloys and B 120 VCA heat treated to the 170,000 psi. yield strength and 180,000 psi. ultimate strength level.

Again illustrating the controlling effect of external conditions on the relative ratings of materials, aluminum is at the top and 17-7 PH steels at the bottom of the merit rating at low stresses, but reverse their relative ratings at the maximum practical stress. The titanium alloy is also best above 400° F. for all stresses and best at all temperatures at the maximum practicable stress.

By employing procedures he developed to characterize optimum stiffened panels, Prof. George Gerard investigated a wide variety of magnesium, aluminum, titanium and precipitation hardened stainless steel alloys for crippling efficiencies. By considering the best material in its temperature range for a given alloy class, he obtained results which are representative of the best currently available properties at the time his study was published in the January 1958 *Journal of Aeronautical Sciences*.

The results of this analysis are shown in Fig. 3 for which Gerard used the following room-temperature yield strengths:

	Compressive Yield Strength
Aluminum	81,000 psi.
Magnesium alloys	27,000
Titanium (8 Mn)	121,000
PH steels	230,000
Inconel X	115,000
DOD	160,000
B 120 VCA	190,000

Gerard uses the structural index fN/b to characterize the crippling strength of stiffened panels and V-groove plates, which, he points out, are most representative of the airframe structure. In this index f equals form factor, N equals compressive loading in psi., and b equals the total width of the stiffened panel in inches.

In Fig. 3, right, the target properties for the DOD titanium alloys were used in place of the older Ti, 8 Mn titanium alloy in the annealed condition. B 120 VCA also meets the DOD target properties with some margin to spare.

Crippling criteria include the effect of elastic modulus on buckling, and so it is clear from the foregoing that titanium's lower modulus relative to steel by no means outweighs its density advantage. In sandwich construction, where buckling is prevented by the structure, titanium's density advantage is completely freed from modulus considerations.

In actual practice the advantage of B 120 VCA honeycomb over the precipitation hardening steels appears to be much greater. In the one strictly comparable test that has been run to date between identical honeycomb panels of heat treated 17-7PH and heat treated B 120 VCA, Boeing Airplane Co. found the beam strength of the precipitation hardening steel to be less than half that of the B 120 VCA even though it weighed more than one third more. Precipitation hardening steel has hitherto given the highest strength-weight honeycomb structure. It is

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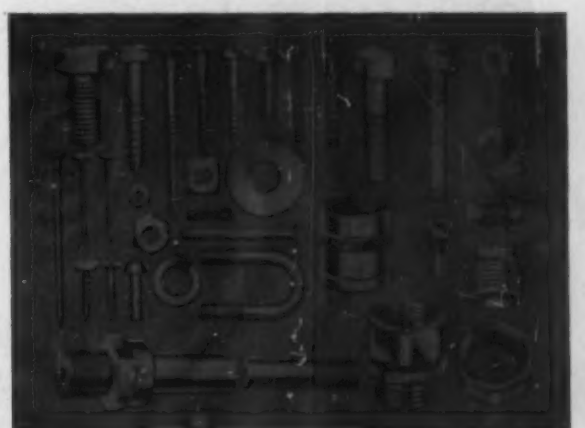

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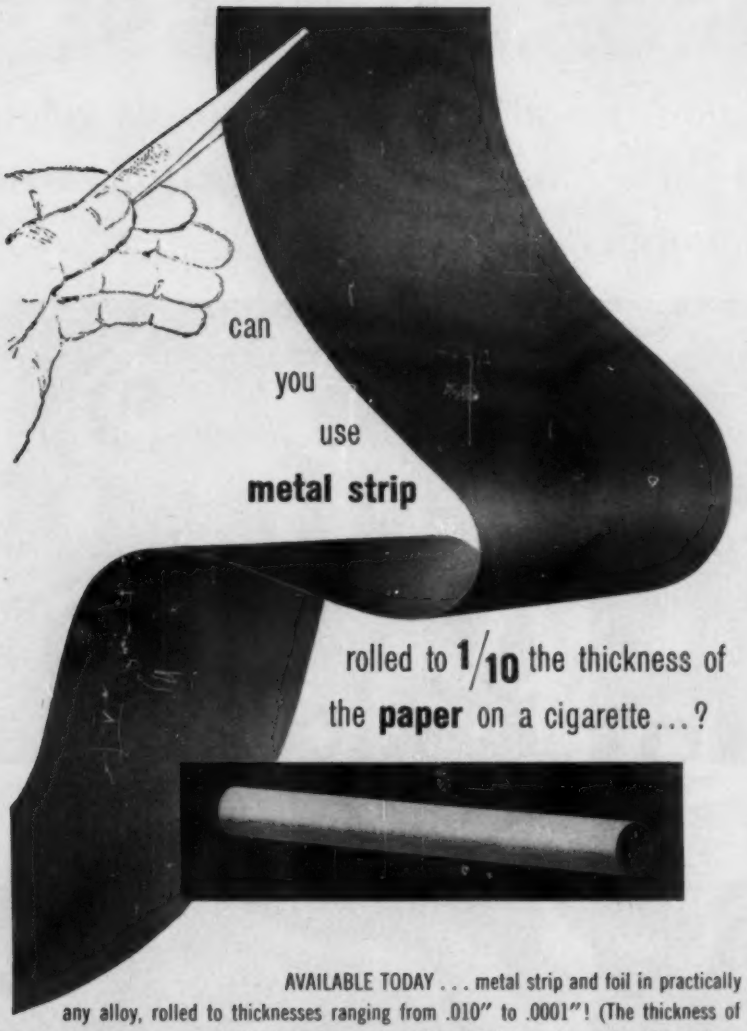

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Titanium Alloys . . .

truly a technological breakthrough, therefore, to double the strength and cut the weight to two thirds.

As indicated in the foregoing, the newer titanium sheet alloys are the formable-soft, ageable-strong alpha-beta DOD alloys and the beta alloy, B 120 VCA.

As pointed out earlier, aluminum exerts a controlling influence on the long-term hot strength properties of the DOD alloys – the higher the aluminum, the higher the creep strength. There is an additional relationship: the higher the aluminum the poorer the formability. Other relationships such as those of aluminum content and aged tensile properties are less clear.

C 120 AV is in regular production. The other two DOD titanium sheet alloys, Crucible C 115 AMoV and C 105 VA, are in pilot production and are being extensively evaluated in several airframe plants.

The target guaranteed minimum tensile values for B 120 VCA, are tabulated below:

0.2% Yield	Ult.	Elong.†
120,000 psi.*	125,000 psi.*	10
170,000	190,000	6
180,000	200,000	5
190,000	210,000	4
200,000	220,000	3
220,000	240,000	2

The preceding strength-weight discussions have served to outline the strength characteristics of B 120 VCA. The following additional advantages can be listed for this alloy:

1. Good mill producibility.
2. Good shop fabricability.
3. Ductile weldability.
4. No special heat treating equipment required.
5. Formable-soft, ageable-strong.
6. Nondirectional sheet and strip.
7. Low scratch sensitivity.
8. No shear cracking or delayed cracking tendencies.
9. Relatively high tolerance for hydrogen.
10. Good brazeability.
11. Good cold headability.

The alloy is in pilot production and appreciable quantities are being evaluated by a number of airframe

(Continued on p. 145)

*In formable condition. All others are aged.

†% in 2 in.

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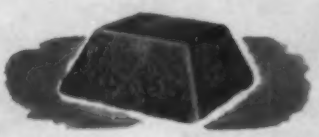

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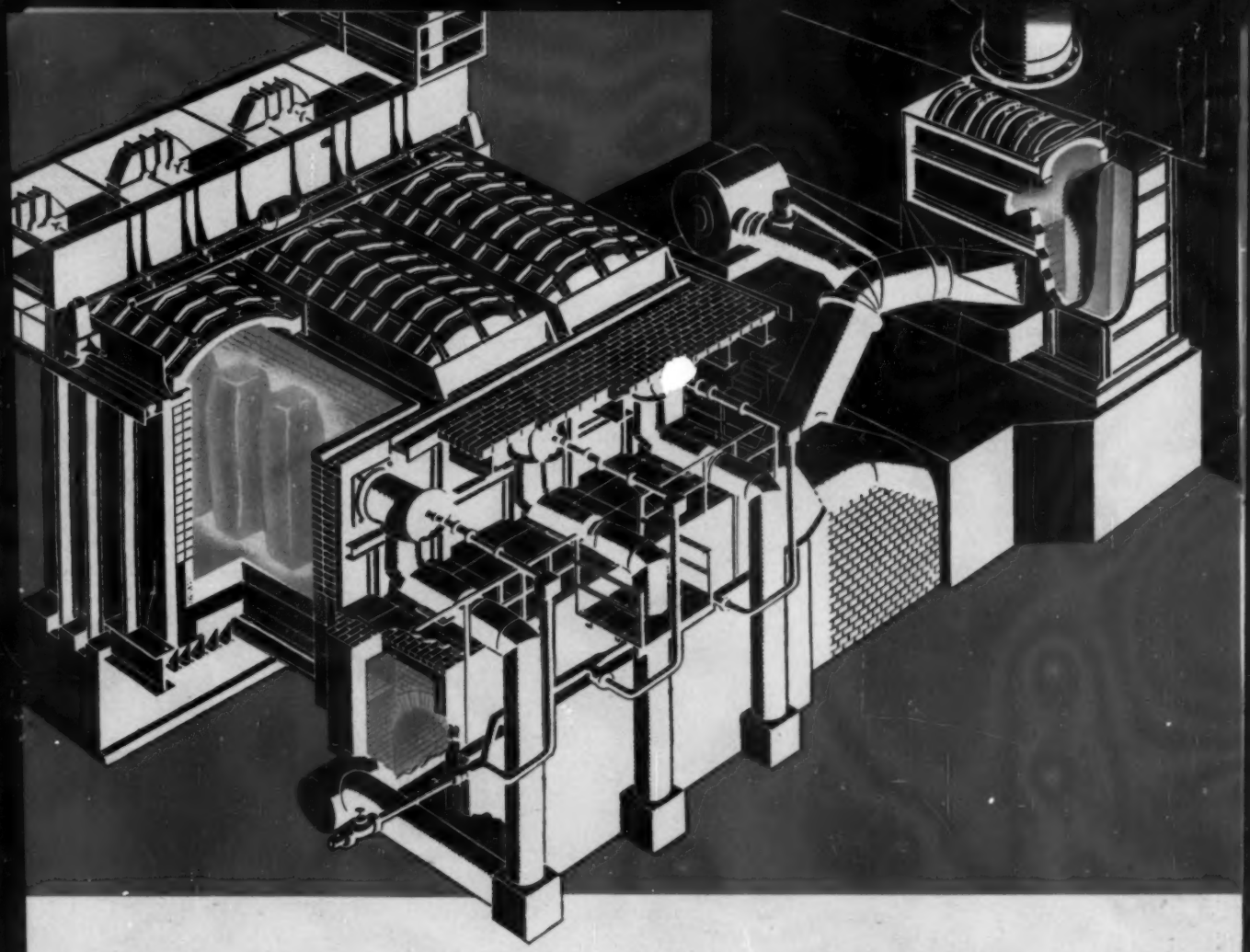

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In the past, the all-alpha A 110 AT (5 Al, 2.5 Sn) and the aluminum-strengthened alpha-betas, C-130 AM (4 Al, 4 Mn) and C 120 AV (6 Al, 4 V), were used in the annealed condition for such applications. The titanium industry is now guaranteeing minimum heat treated properties in the alpha-beta alloys and these are up to 40% higher than the annealed properties. In addition Crucible has recently placed a higher-strength alpha-beta forging alloy, C 135 AMo (7 Al, 4 Mo), into regular production, and has a new super all-alpha alloy, RC 900 (12 Zr, 4 Al), in pilot production.

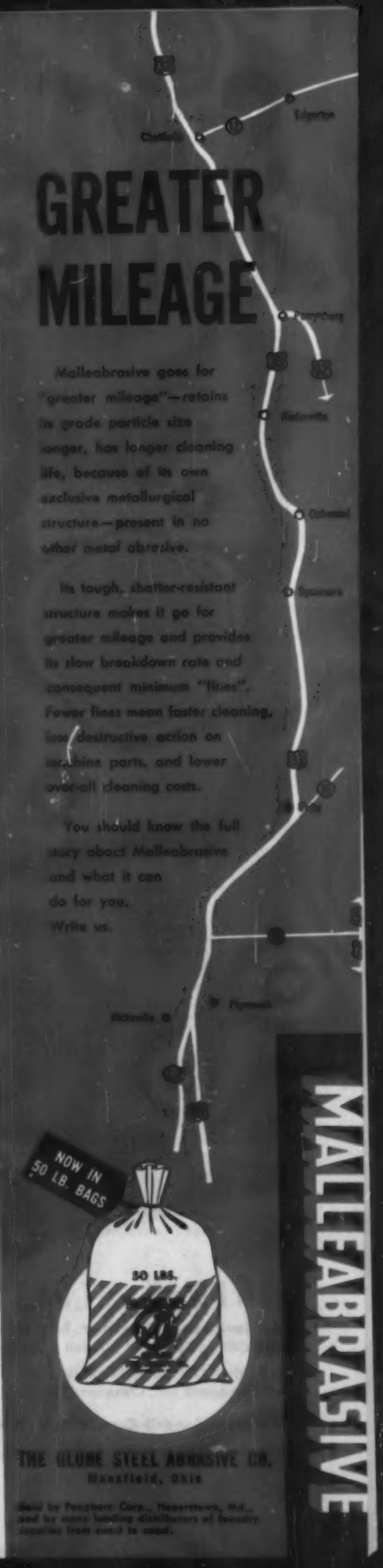
The relative position of these alloys from the standpoint of strength-weight as a function of temperature is given in Fig. 2.

C 120 AV (6 Al, 4 V) has been in production for several years and is deservedly popular. The aluminum was raised and molybdenum was substituted for the vanadium in designing the new alloy C 135 AMo (7 Al, 4 Mo) in order to attain higher room and elevated temperature strength and greater hardenability. D. R.

Chlorine Improves Aluminum Weld

Digest of "Chlorine Additions for High-Quality MIG Welding of Aluminum Alloys", by M. B. Kasen and A. R. Pfluger. Paper presented at Western Welding, Brazing and Heat Treating Conference, Stamford Research Institute, Menlo Park, Calif., March 1958.

THE INERT-GAS METAL-ARC (MIG) process is capable of producing welds of excellent quality in a variety of aluminum alloys when the welding equipment is functioning properly and when the parent metal and filler metal are clean. However, despite all reasonable precautions, welds made under shop and field conditions frequently contain poros-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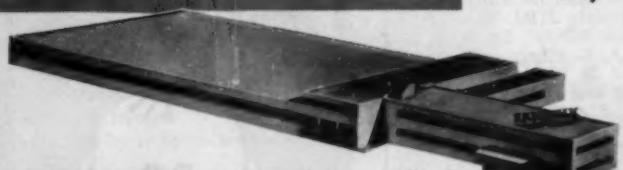

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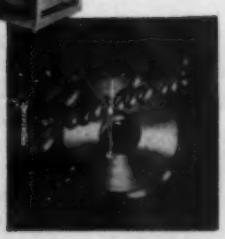

SS-169

Chlorine Additions . . .

ity and dross in excess of code limitations.

Most weld porosity and dross come from contaminants on the filler wire surface. The high ratio of wire surface area to the volume of deposited metal will introduce excessive concentration of contaminant into the weld despite a relatively low concentration of contaminant per unit area of wire surface.

Porosity and dross may also result from poorly cleaned parent plate or may be introduced into the weld through the use of impure shielding gas, or ineffective shielding due to arc instability. Simple cleaning procedures prior to welding can eliminate the plate as a source of contamination. The high standards of purity being maintained by the producers of inert shielding gases have largely eliminated this source of unsoundness. Likewise, improvements in welding equipment have done much to eliminate unsoundness arising from arc instability.

Commercial production of filler wire free of surface contaminants has been a more difficult problem. The economics of manufacturing require that the wire be cleaned and spooled at a very rapid rate, yet cleaning treatments require time to be effective. Thus, a balance between quality and cost of manufacture has to be established by each fabricator of welding wire. Thus it would seem that the problem of contaminants has been solved, although at a considerable increase in the cost of the welding operation. Why, then, do fabricators continue to be troubled with porous and drossy welds? Primarily this is attributed to recontamination of the filler wire during storage or while in use.

The effect of chlorine addition was first observed in a weld made with an aluminum-magnesium filler wire which had been known to produce welds of poor quality. Introduction of a small amount of chlorine into the argon shielding gas stream during the welding operation caused a significant improvement in the quality of the weld as determined by radiography.

Subsequent tests repeatedly demonstrated that chlorine additives were effective in reducing the level of both porosity and dross in MIG

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Chlorine Additions . . .

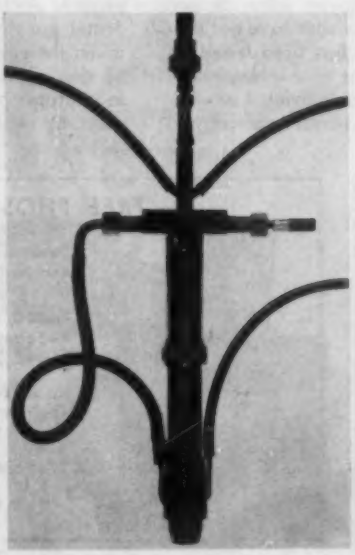
welds. As a result, a significant improvement in static mechanical properties occurred. When the welding torch was modified to permit the chlorine addition to be made through the contact tube, substantial improvement in the effectiveness of the chlorine was achieved.

Accurate assessment of the effectiveness of the chlorine additive depends upon precise knowledge of control weld quality, that is, the quality that will result in the absence of chlorine. Naturally contaminated wire is inadequate for control purposes because of variation in the amount and type of contaminant. Furthermore, determination of the precise type of contaminant is a formidable technical problem.

Precise control was achieved by introducing known quantities of specific contaminants directly into the arc area while welding with a high-quality filler wire. Thus, various levels of weld quality were produced in the tests.

Hydrogen, propane, water vapor and oxygen were introduced into the arc area to simulate the presence of hydrated oxides and hydrocarbons on the filler wire surface. These contaminants, introduced into the arc through a contact tube, closely simulate the liberation of contaminants from the surface of a contaminated filler wire. The welding torch was modified as shown in Fig. 1 and 2. Two tubes were inserted into the uppor portion of the welding torch. The desired contaminant was introduced through one tube while the chlorine was introduced through the other.

Fig. 1 — Automatic MIG Welding Torch Adapted for Simultaneous Introduction of Contaminant and Chlorine to the Arc Area



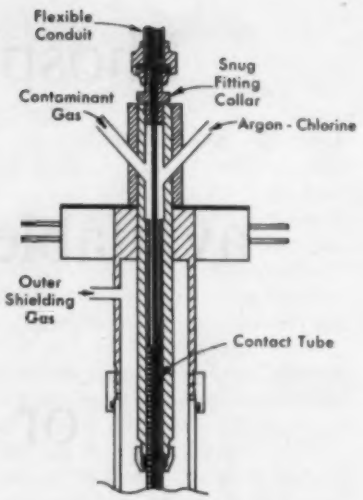
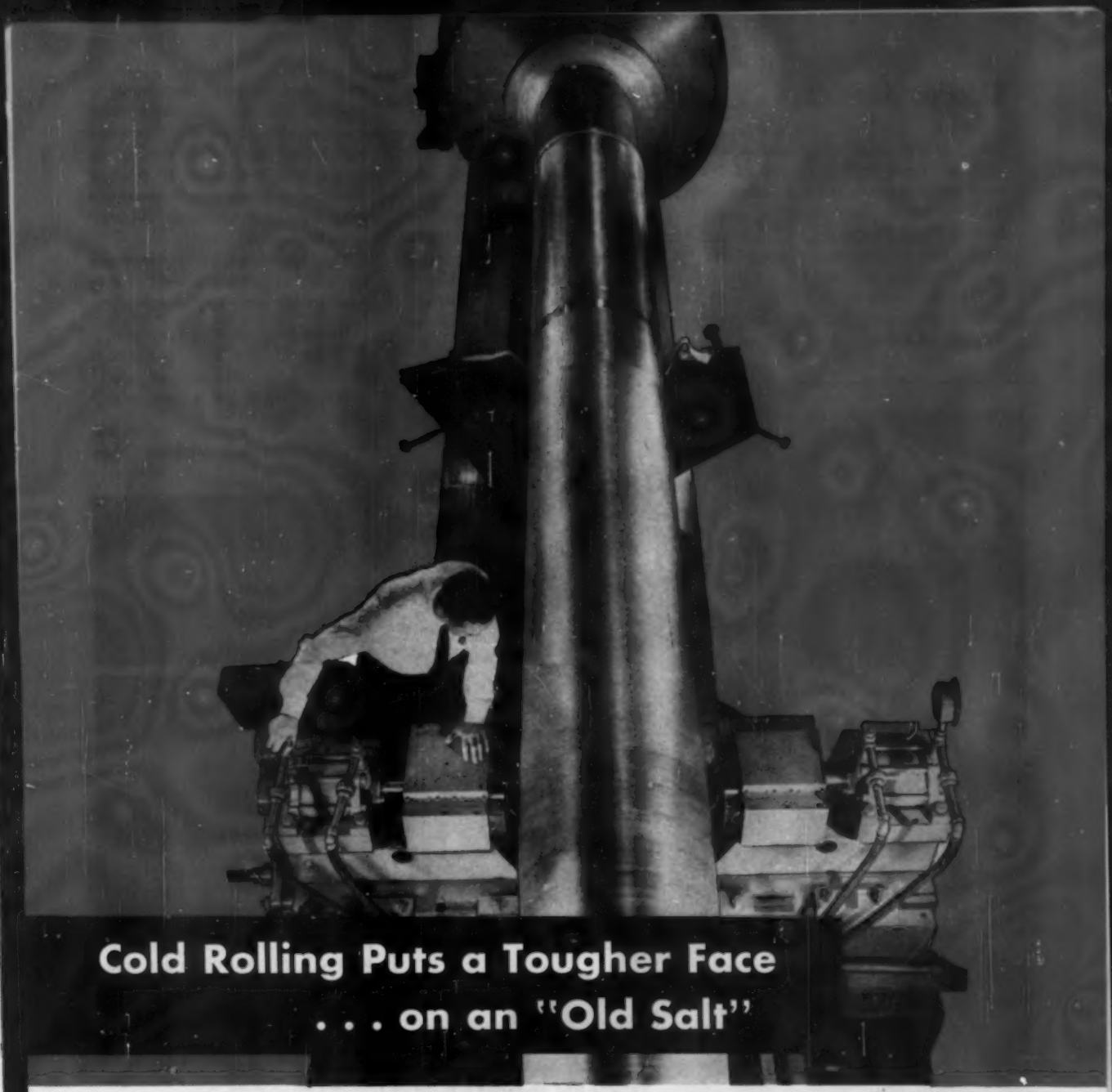


Fig. 2 — Section View of Upper Portion of the Automatic Welding Torch Shown in Fig. 1. Contaminant and chlorine gases surround the welding wire in contact tube; outer shielding gas envelopes the other two

Minute quantities of both contaminant and chlorine passing through the contact tube were measured accurately by metering known mixtures of argon plus the additive whenever the amount of additive was so low as to cause metering problems. Thus hydrogen was added as a 5% mixture, propane as a 1% mixture and chlorine either as a 3% or a 0.5% mixture by volume. The water vapor addition was controlled by passing various quantities of moist argon into the arc area. The flow rates of the additives were metered at the exit end of the contact tube with the filler wire in place.

The parent material was ⅜-in. thick 5083 aluminum alloy. The filler wire was 5183 aluminum alloy of 3/32 in. diameter.

A rectifier power source having a rising volt ampere characteristic was used throughout the program. All welding was automatic with stationary torch and moving workpiece. A 60° V-groove joint design was



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Chlorine Additions . . .

used and the welds were completed in either three or four passes. All welds were made in the flat position with an argon outer shielding gas flow of 60 cu.ft. per hr.

The parent alloy was cleaned by caustic etching followed by a nitric acid rinse. Wire brushing between weld passes constituted the only additional cleaning. All filler wire used in this portion of the investigation was required to produce radiographically clear multiple-pass welds under normal conditions.

The quantity of each specific contaminant necessary to produce a weld of very poor quality was determined by adding varying amounts of each contaminant to a series of welds. The series produced with the hydrogen additive is illustrated in Fig. 3. Similar series were run with propane, water vapor and oxygen. Radiography was used to evaluate all the porosity-forming contaminants – hydrogen, propane and water vapor. The effect of oxygen was evaluated by fracture examination since this contaminant produced dross not easily detected by radiography.

The quantities of contaminant necessary to produce a weld of very poor quality were as follows:

Hydrogen	8.5 cc. per min.
Propane	1.3 cc. per min.
Oxygen	210 cc. per min.
Water vapor	1.4 g. per min.

A series of thirteen welds was then made in each contaminant series with the above control level of contaminant present in each weld and with chlorine flows of either 0.5, 1.5, 3.0, 10 or 20 cc. per min. Each series also included welds with no chlorine addition. The resulting welds were evaluated either by radiography or by examination of fractures as noted above.

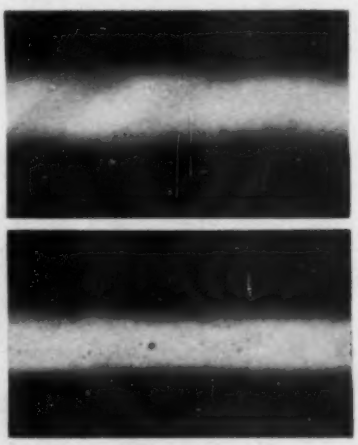

Fig. 3 – Radiographs Illustrating the Interrelationships Between Weld Porosity Level and Hydrogen Content. Upper weld was inoculated with 0.45 cc. and the lower with 8.7 cc. hydrogen per min.

The deleterious effect of each of the contaminants studied was completely counteracted by additions of 20, 10 or 3 cc. per min. of chlorine to the arc area during welding.

The process was carried a step closer to practical conditions by a study of the effect of chlorine additives on the quality of multipass flat-position MIG welds made with purposely contaminated filler wire. Two filler wires, both of 5356 alu-

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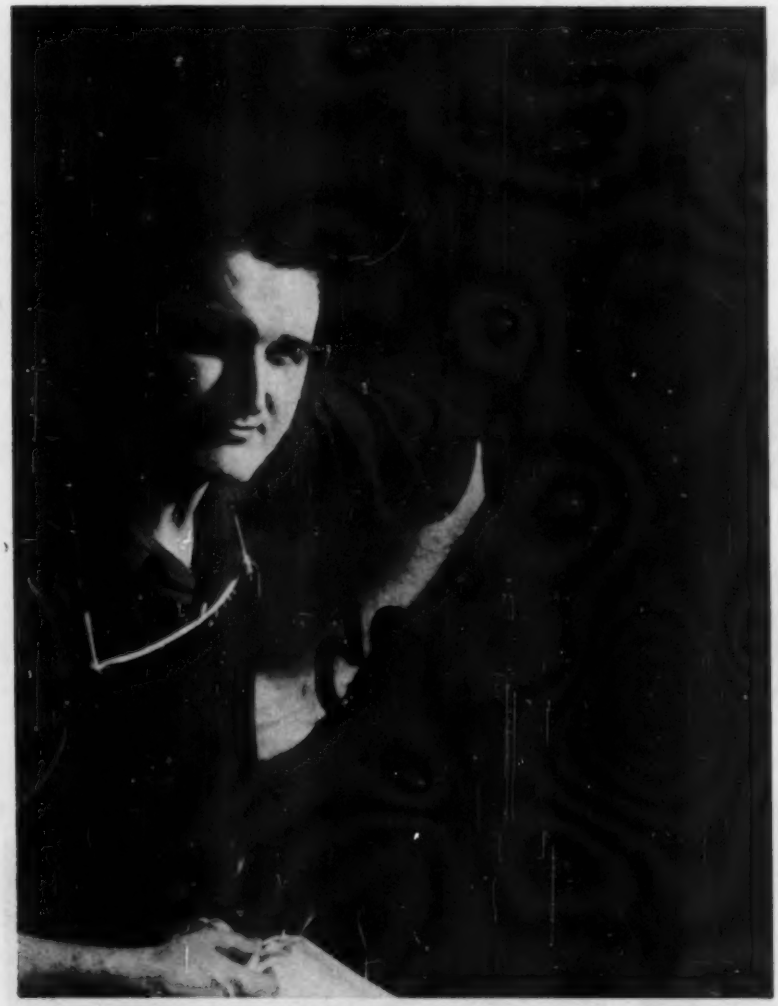

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Chlorine Additions . . .

minum alloy, were used in this study. A hydrated oxide was produced on one wire by heating it in steam. The other wire was used in the as-drawn condition, that is, with the normal amount of residual drawing lubricant on the wire surface. A chlorine additive of 20 cc. per min. completely counteracted the deleterious effect of hydrated oxide and a radiographically clear weld was produced.

Clean filler wire may become contaminated during storage and cause weld unsoundness. Thirteen spools of 3/32 in. diameter MIG filler wire of the aluminum-magnesium type were evaluated with and without chlorine addition to the arc area. These wires, commercially produced by three major suppliers, had been kept in dry storage for periods up to three years.

A conventional argon weld and a weld with chlorine addition were made consecutively in ½-in. plate for each spool of wire. All 13 welds made with chlorine additive were radiographically clear. Three of the 13 conventional welds contained porosity to an extent approaching that of the control welds in the gaseous contaminant series.

These data indicate that the addition of minute quantities of chlorine to the arc area during flat-position MIG welding of aluminum-magnesium type alloys will effectively counteract hydrogen, propane, water vapor and oxygen when each contaminant is present in the arc area in sufficient quantity to seriously affect the quality of the welds. Furthermore, the data indicate that chlorine additions are effective in counteracting the deleterious effects of contaminants on the filler wire surface.

D.R.

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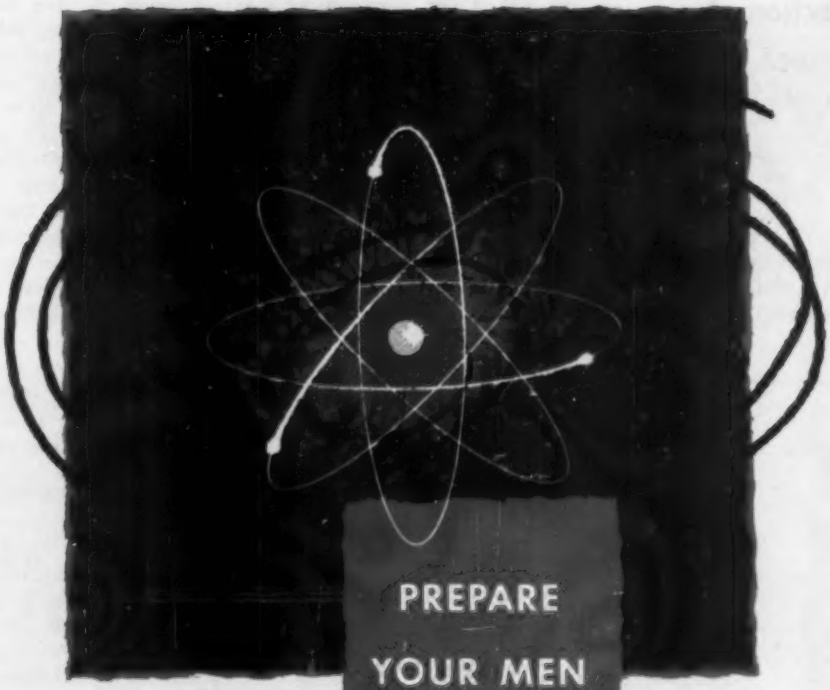

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Production of Fourdrinier Wire

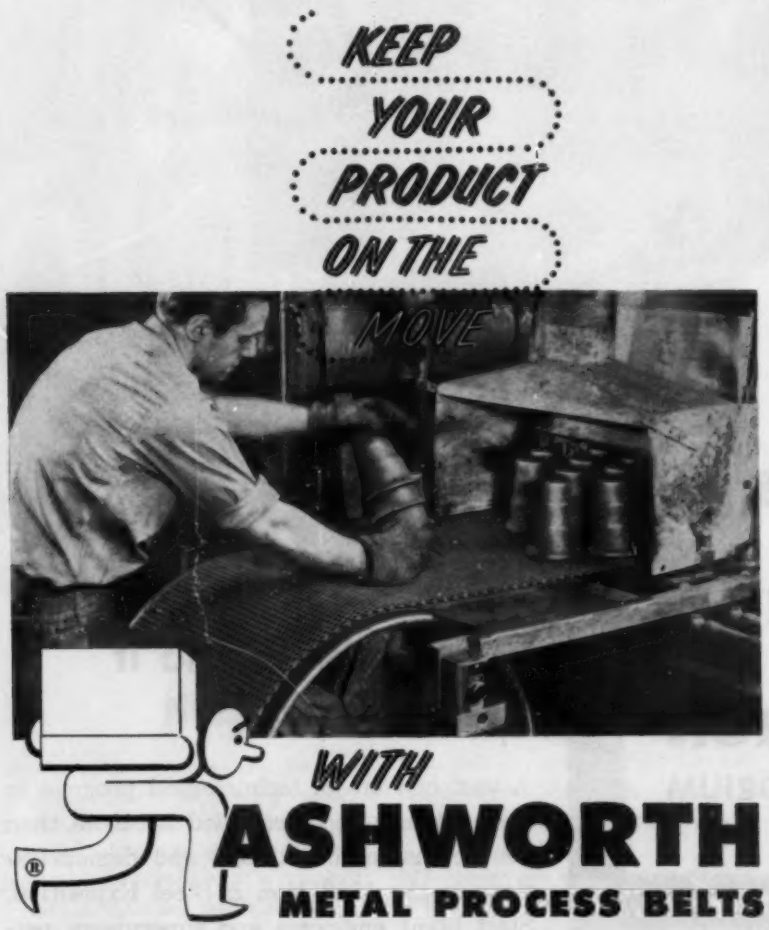
Digest of "Metallurgical Problems in the Production of Woven Wire Cloth", by J. Waring, *Journal*, Australian Institute of Metals, Vol. 2, December 1957, p. 220-232.

FOURDRINIER or paper-making wires, referred to as "wires" in the trade, are a specialized form of woven wire-cloth belts fitted to the wet end of the paper-making machine to convey and dewater the paper pulp to form a uniform mat or sheet of fiber.

In this article, the author reviews the service requirements, describes the production methods, and examines the metallurgical problems involved in the manufacture of Fourdrinier wires. The wire is formed by weaving together warp and weft wire in a wire-weaving loom and then joining the ends by either individually welding warp wires together or by hard soldering the ends to form an endless belt. These fine-woven belts are made in a wide range of sizes up to 22 ft. wide by over 100 ft. long and run on the paper-making machine at speeds up to 3600 ft. per min. The warp wire, which runs the length of the machine, is usually made from 8% tin phosphor bronze and the weft is usually 80-20 brass. The warp-wire knuckles on the underside of the machine wire are subjected to abrasive wear, due to their contact with the tops of the suction boxes fitted to the paper-making machine to assist in the dewatering process. This frictional load, together with the load required to drive the wire and convey the pulp, imposes a tensile strain on the warp wires. Thus, it is desirable that the warp wire alloy should have a high tensile strength, good resistance to abrasion and corrosion fatigue. The woven wire cloth must have uniform drainage characteristics throughout and, to avoid "wire mark" on the underside of the paper, the top surface must be smooth and uniform. Wire mark can be reduced by grinding the top surface or by using flat warp wire.

The 8% tin phosphor bronze wire is specially made for the industry to rigid specifications. The author points out the difficulties which have been experienced in casting phosphor bronze wire bars to prevent porosity and segregation. Reference is made to degassing and slow pouring techniques developed by Lep and Pell-Walpole, and applied by Bond-Williams. In the author's opinion, most of the breakages when drawing down to fine sizes are due to defects in the original wire bar. The cast wire bars, reduced by cold rolling and drawing, are supplied to the weaving industry in the form of wire about 0.040 in. diameter. The 80-20 brass wire, which is used for the weft, is also supplied at this size. Both the bronze and brass wire are drawn down on multidie slip-type wiredrawing machines using diamond dies with an emulsifiable oil as a lubricant, the drawing speed being around 3000 ft. per min. The hard drawn phosphor bronze wire is continuously annealed in a strand annealing furnace and wound on to

(Continued on p. 158)



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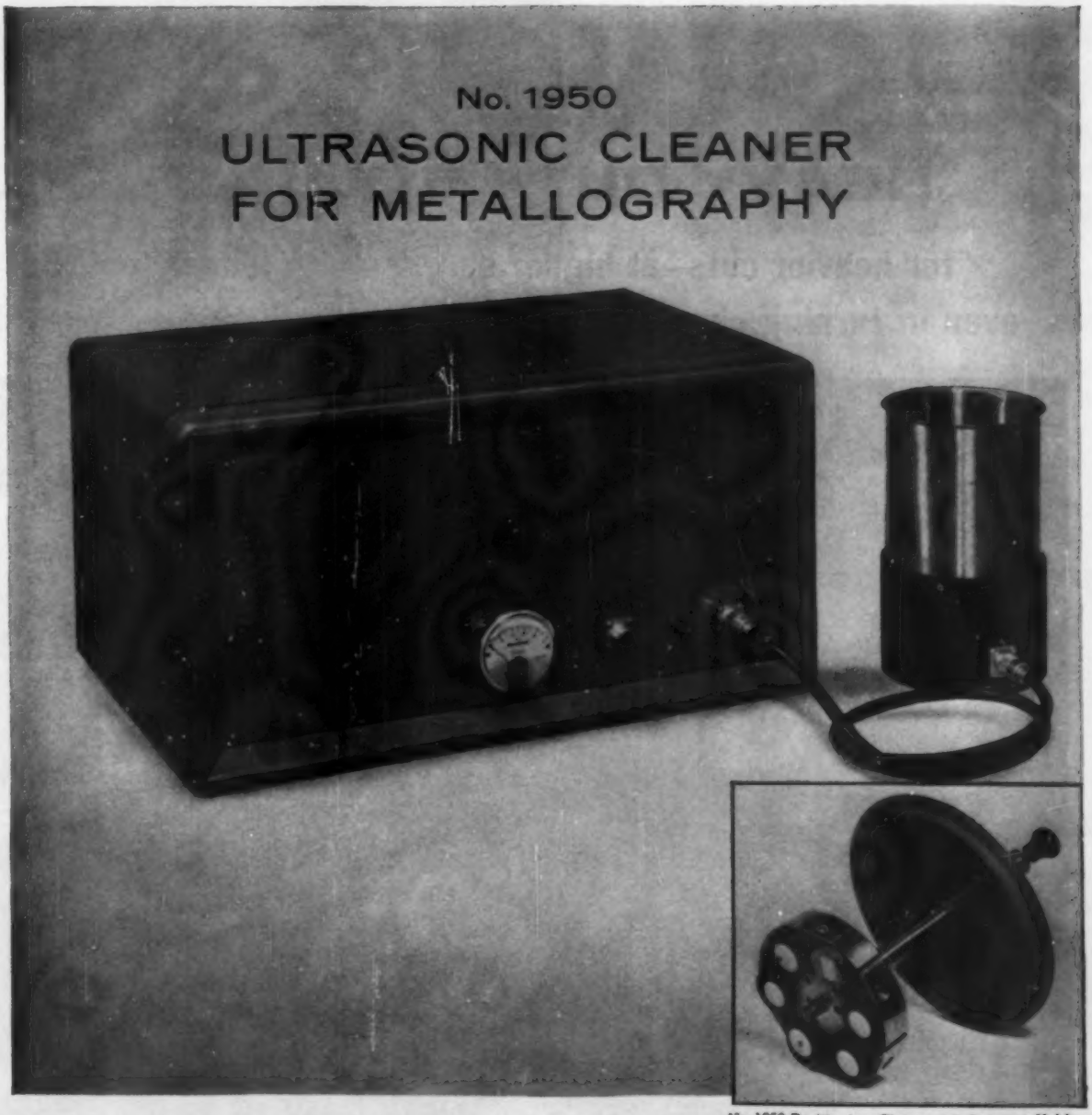

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Fourdrinier Wire . . .

bobbins. An atmosphere of burnt Town's gas is used to prevent oxidation. The 80-20 brass wire is also continuously annealed, but difficulty is sometimes experienced due to volatilization of the zinc.

After testing and segregating, according to temper, the bronze warp wire is wound onto the warp beam fitted to the wire-weaving loom, the number of strands per inch being determined by the desired mesh. The warp wires are threaded through the wire-weaving loom and the weft is introduced by fitting cops of weft to a shuttle. Considerable care is taken during the weaving process to insure uniformity of mesh. A typical mesh is 60 warp wires to the inch and 48 weft wires to the inch. When woven, the length of cloth is inspected and formed into an endless belt by either welding the individual warp wires together or by hard soldering the ends together. The endless belt is mounted on a stretching frame, stretched and run to simulate the mill conditions. At this stage, the surface may be ground to reduce the level of the projecting knuckles on the top side. After a final inspection, the wire is carefully packed and despatched to the paper mill.

Finally, the author refers to dezincification and stress-corrosion cracking of the brass weft when in service on the paper machine.

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Stress-Raisers in Engineering Parts

Digest of "Some Common Stress-Raisers in Engineering Parts", by G. A. Cottell, *Technical Report*, British Engine, Boiler, and Electrical Insurance Co., Ltd., New Series, Vol. 3, p. 91-112.

FATIGUE FAILURES in service are largely attributable to some factor (termed stress-raiser) which intensifies the stress in a localized area to a level greater than the material can withstand for the number of cycles that correspond to a normal service life.

A common example of a stress-raiser is a small hole drilled in a wide strip of elastic, homogeneous, isotropic material. If this material is subjected to a uniaxial tensile stress "f" in a direction parallel to the edges of the strip, the stress at the edges of the hole will reach a maximum value of "3f" if the elastic limit is not exceeded. If the shape of the hole is changed to an ellipse with the long axis "b" perpendicular to the direction of the applied stress and the short axis "a" parallel to it, the maximum stress is given by the following formula:

$$f_{max} = f\left(1 + \frac{2b}{a}\right)$$

This stress is found at the ends of the "b" axis. As the ratio of b:a is increased, the stress is also increased until it becomes infinite when the ellipse becomes a straight line. This is confirmed by practical experience which shows that a sharp-ended crack transverse to the tensile load is the most effective type of stress-raiser.

The previous theories are based on the assumptions that the loading

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Stress-Raisers . . .

is static and that the elastic limit of the material is not exceeded. If, however, the yield point of the material is reached, plastic deformation occurs and relieves the stress peaks. This indicates that the stress intensification factor reaches its calculated value at small loads but decreases at large loads. It is now accepted that the effect of the stress-raiser is a function of the size of the part containing it and achieves its full adverse effect above a certain size.

Of particular importance to engineers is the variation in the notch sensitivity of different metals. Stress-raisers of the same magnitude do not exert the same effect on different metals or even on different alloys of the same class. In general, most metals are notch sensitive, with the notable exceptions of cast iron and 18-8 stainless steel. (The endurance limit of cast iron is so low that notches have no appreciable effect.)

Experiments have demonstrated that although the endurance limit of steel increases with tensile strength on unnotched specimens, it attains a maximum value of 160,000 psi. and then decreases with notched specimens. This indicates that no advantage is gained from the fatigue point of view by using steel in the highest tensile range. However this is not true of 4340 steel.

In general, stress-raisers fall into one of the following groups:

1. Those resulting from changes in geometry, such as different diameters, broad integral collars, holes, keyways, threads.

2. Those resulting from surface discontinuities, such as nicks, notches, machine tool marks, corrosion pits.

3. Those inherent in the material, such as local discontinuities, nonmetallic inclusions, voids.

In the majority of cases, these could be eliminated or their effects substantially reduced by the application of the elementary principles of fatigue failure prevention. In this connection, it would be well to keep in mind the fact that the majority of fatigue failures are traceable to design and production defects and only a few are due to material or heat treatment defects.

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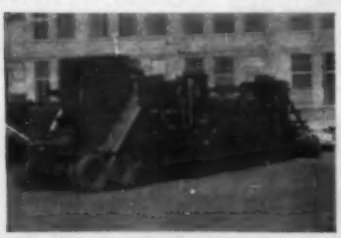

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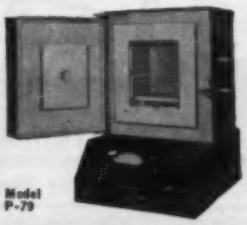

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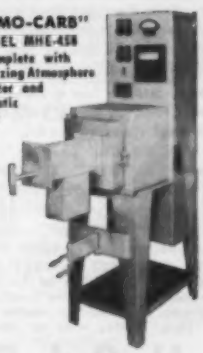

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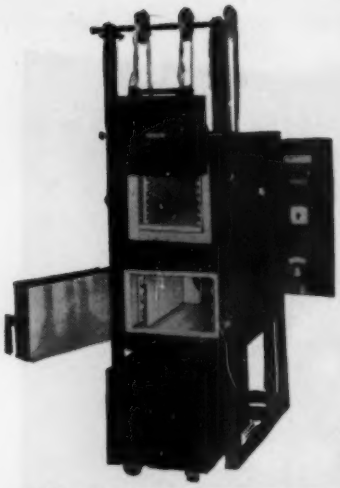

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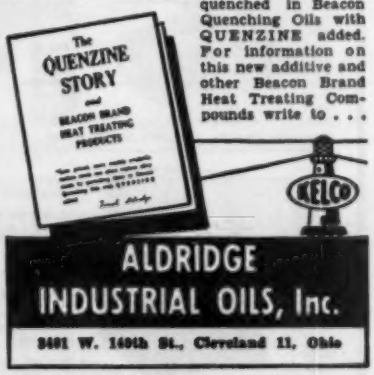

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HEAT TREATING S EQUIPMENT

Stanwood is one of the oldest organizations devoted to the design and manufacture of heat treating equipment exclusively for heat treaters and metal working plants throughout the nation.
Stanwood has the experience, the organization and the facilities.
Representatives in major cities, Send for Catalog.

STANWOOD CORPORATION
4817 W. CORTLAND STREET CHICAGO 39, ILLINOIS

LIST NO. 12 ON INFO-COUPON PAGE 168

STEEL FABRICATED and RUBBER-LINED TANKS for the Plating Industry

ARco

- Plating tanks any size or shape fabricated and rubber-lined to your specifications. A complete service from basic design to installation, also fabricated and rubber-lined pipe and fittings. Write Dept. "MP" for complete details.

Subsid. of Automotive Rubber Co., Inc.

ARco STEEL FABRICATORS • INC.
12542 BEECH ROAD • DETROIT 39, MICH.

LIST NO. 153 ON INFO-COUPON PAGE 168

WIRETEX *fabricated*

PLATE POTS

Last longer.... cut operating costs
fast delivery..low cost

Before you buy any salt pot, or if you have other heat and corrosion resistant problems —SEE WIRETEX.

WIRETEX PLATE POTS withstand temperatures up to 2100°! Cut neutral or cyanide bath costs! Last 15 to 20% longer! Operating costs drop 25 to 35%! Down time is almost halved!

- All metals
- I.D. dia. up to 24" and larger
- Depths unlimited
- Dished bottom heads
- Overlapping seams
- Double x-ray quality weld, inside and out
- Heavy steel flanges
- Stress relieved
- Sand-blasted finish

Before you buy any salt pot, or if you have other heat and corrosion resistant problems—SEE WIRETEX.

Wiretex mfg. co. 5 Mason St., Bridgeport 5, Conn.
Specialists in Processing Carriers Since 1932

LIST NO. 114 ON INFO-COUPON PAGE 168

RUST-LICK IN AQUEOUS SYSTEMS

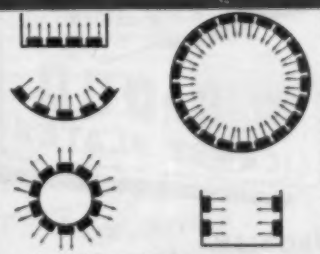
Eliminates RUST & Fire Hazards Non-Flammable Non-Toxic

Send for Brochure: The ABC of Rust-Lick for Rust Prevention

PRODUCTION SPECIALTIES, INC.
755 BOYLSTON STREET
BOSTON 16, MASS.

LIST NO. 105 ON INFO-COUPON PAGE 168

ULTRASONIC CLEANING



Typical Transducer Arrangements

SONOGEN®

Ultrasonic-Power Generators with hermetically-sealed barium-titanate Transducers — 40Kc/sec.

Transducer Radiating Areas of ¼ sq. ft. to 10 sq. ft. — for use in solvents and detergents.

Eliminates hand operations — Reduces rejects in plating, finishing, assembly.

For washing, degreasing, removal of buffing compounds, radioactive contamination, soldering flux, plaster, carbon smut, etc.

Literature upon request.

BRANSON ULTRASONIC CORP.
Specializing in Ultrasonics Since 1946
[illegible] STAMFORD, CONNECTICUT

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WANTED

SIX PLUS FURNACES

REWARD

WE PAY CASH FOR SURPLUS INDUSTRIAL FURNACES AND RELATED APPARATUS

SURPLUS FURNACES FOR SALE

BOX TYPE

24x36x18	Lindberg	50KW	2000°F
36x72x23	G.E.	72KW	2000°F
48x84x24	American	100KW	1850°F
24x36x14	Surface	Gas	1850°F
54x96x24	Surface	Gas	1850°F

PIT TYPE

20x22	G.E.	48KW	1200°F
28x28	Lindberg	52KW	1250°F
48x72	Lindberg	Gas	1250°F
48x96	Surface	Gas	1250°F
48x96	Lee Wilson	Rad. Tube	1850°F

CONVEYOR TYPE RECIRCULATING

72x40'x30	Surface	RlrHrth Gas	1250°F
27x15'x12	R&S	MshBlt Gas	1250°F

BOX TYPE RECIRCULATING

6'x12'x42"	Lindberg	Gas	1250°F
66"x16'x76"	Lindberg	180KW	1250°F
60"x10'x42"	Lindberg	180KW	1250°F
42"x16'x30"	Lindberg	120KW	1250°F

BOX & CONVEYOR OVENS

6'x30'x18"	Mich Oven Conv	150KW	550°F
6'x30'x18"	Mich Oven Conv	150KW	400°F
5'x16'x12"	Mich Oven Conv	150KW	800°F
2'x2'x4'	Rockwell Box	5KW	550°F
7'x7'x7'	Young Bros Box	Gas	650°F
19"x19"x19"	Despatch Box	5KW	850°F

BRAZING TYPE

18"x42"x12"	Lindberg Pshr	60KW	2500°F
18"x42"x10"	Westinghouse Pshr	50KW	2050°F
62"x18'x24"	GE RlrHrth	655KW	1650°F

SEND FOR COMPLETE LIST

THE JOE MARTIN CO., INC.

19256 John R. St. TWinbrook 2-5500 Detroit 3, Mich.

LIST NO. 160 ON INFO-COUPON PAGE 168

Sel-Rex®

PRECIOUS METALS FOR INDUSTRIAL PLATING

BRIGHT GOLD

Mirror-bright finish in any thickness directly from the bath. Patented

PUR-A-SALTS

Restores contaminated cyanide plating baths to full, trouble-free operation. Patented

SILVREX BRIGHT SILVER

Crystal-clear solution that produces mirror-bright deposits. Patented

SILVER SOL-U-SALT

Non-dusting — safest and easiest to use.

BRIGHT RHODIUM

Brilliant, fine-grained non-tarnishing deposits.

RHODEX

Only rhodium electroplating process that yields extra heavy compressively stressed deposits. Patent Pending

ACID GOLD PLATING PROCESS

Developed specifically for plating printed circuits. Mildly acid so that neither the laminate nor the adhesive at the inter-face of printed circuit boards are affected during the plating process.

Complete installation and servicing on all precious metals processes.

SEL-REX CORPORATION

Dept. BB, Nutley 10, New Jersey

Offices: Detroit, Chicago, Los Angeles

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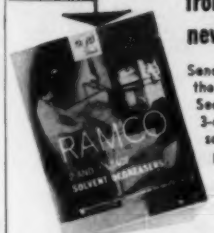
Q A **METAL PARTS CLEANING PROBLEMS?**

Get the answers RIGHT from RAMCO'S new BULLETIN!



Send for your copy of the Ramco Bulletin. See how Ramco 2- and 3-dip degreasers can solve your metal parts cleaning problems, economically, efficiently, safely! Write today!

RAMCO EQUIPMENT CORP.
DIV. OF RANDALL MFG. CO., INC.
809 Edgewater Rd., New York 39, N.Y.

LIST NO. 128 ON INFO-COUPON PAGE 168

How Roll Coater *Pre-Painted* METAL SAVED MONEY AND IMPROVED QUALITY ON **R-C-000 LICENSE PLATES**

PROBLEM:

Stello Products Company, Logansport, Indiana, manufacturer of tags, license and "booster" plates, had the problem of excessive direct labor charges. In the previous expensive method of making these items, plates had to be stamped from bare metal —and then cleaned individually—and spray painted on both sides. This method did not give the uniform quality demanded—and Stello turned to Roll Coater for a solution.

SOLUTION:

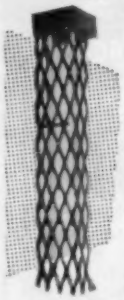
Roll-coated metal was tested by Stello Products Company. *Pre-painted* and *baked* on both sides, this metal eliminated *entirely* the cleaning and spray painting operations—withstood rigorous stamping tests—and relieved painting facilities for other jobs. Says J. C. Cotner, president of Stello Products Company, "Roll Coater metal is now saving us approximately 50% in direct labor costs—and is giving us the desired uniform quality in our plate production. It really solves our problem."

SEND FOR FREE BROCHURE and SAMPLE TODAY!

Roll Coater
INCORPORATED
PENDLETON INDIANA

LIST NO. 155 ON INFO-COUPON PAGE 168

there's a *Glo*-QUARTZ* IMMERSION HEATER for Your Every Heating Requirement



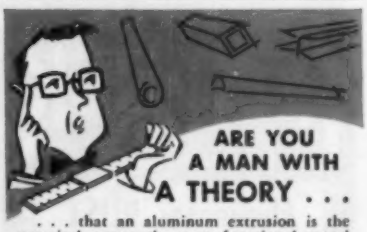
- INSTANT HEATING
- SHOCK-PROOF
- AVAILABLE IN ALL VOLTAGES —WATTAGES, ONE AND THREE PHASE

Available from your Electroplating Distributor

WRITE FOR BULLETIN ▶

Glo-QUARTZ®
ELECTRIC HEATER CO., INC., Willoughby, Ohio
*Reg. U.S. Pat. Off. Phone Willoughby 2-5521

LIST NO. 145 ON INFO-COUPON PAGE 168



ARE YOU A MAN WITH A THEORY . . .

. . . that an aluminum extrusion is the practical approach to a functional metal parts application . . . at a savings in time and money, and without loss in quality? In fact, the properties — you theorized — of extruded aluminum would even be better? If so, G.E.I.'s engineers are ready to consult with you — without obligation, on one part or a million — to determine how practical your idea is. G.E.I. engineers specialize in adapting extruded aluminum to *new* functional roles.

GENERAL EXTRUSIONS, INC.
4940 LAKE PARK RD., YOUNGSTOWN, OHIO. Sterling 3-7481
Missouri, S. Illinois Representative: Frank May Co., 4378 Lindell Blvd., St. Louis 8, Mo.
Michigan Representative: Howard B. Jones, 15842 Kenfield Ave., Detroit 23, Mich.
Southern Distributor: General Extrusions of Memphis, Inc., 4462 Summer Ave., Memphis

LIST NO. 141 ON INFO-COUPON PAGE 168

ARco AIR WASH SYSTEMS

PLATING • PICKLING • METAL CLEANING *FUME SCRUBBING*

• Reasonable initial cost . . . economical in operation . . . no moving parts . . . efficient in performance . . . compact—requires little space . . . standard units—7200 to 57600 C.F.M. Write Dept. "MP" for complete information.

AUTOMOTIVE RUBBER CO. • INC.
12550 BEECH ROAD • DETROIT 39, MICH

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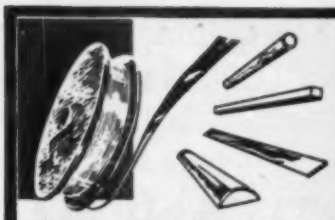

ROUND, SQUARE, FLAT AND HALF-ROUND WIRE FOR MASS PRODUCTION OF SMALL PARTS

Beryllium Copper • Bronzes
Other Non-ferrous Alloys
Rounded or square edges.
Available with hot-tinned finish for solderability.
Write for descriptive folder.

LFA LITTLE FALLS ALLOYS
INCORPORATED
193 Caldwell Ave., Paterson 1, N. J.

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LUBRICATION DATA FOR COLD FORMING OPERATIONS

This technical newsletter is filled with case history reports of successful uses of MOLYKOTE® Lubricants in cold forming operations. A chart shows the metal being formed and the type of MOLYKOTE used together with the proper method of application.

Send for this MOLYKOTE NEWSLETTER today. (Refer to Bulletin 304).

THE ALPHA-MOLYKOTE CORPORATION
Main Factories:
65 Harvard Ave., Stamford, Conn.
71 Arnulfstrasse, Munich 19, Germany

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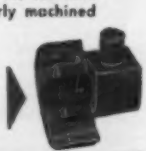
A PROVEN DEPENDABLE SOURCE
FOR BETTER GRADE INVESTMENT CASTINGS IN FERROUS AND NON-FERROUS METALS

INVAR CASTING
Special Feature — Nickel content held to 35% minimum — 36% maximum

STAINLESS STEEL PART for milk bottling unit formerly machined from solid stock. Only finish operations required are reaming small dia. of counterbored hole and drilling and tapping for set screw.



ENGINEERED PRECISION CASTING CO.

MORGANVILLE, N. J.

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GET A BID FROM

HOOVER

SPECIALISTS IN THE FIELD OF
Die Castings
SINCE 1922
Aluminum and Zinc

HOOVER

THE HOOVER COMPANY
Die Castings Division
North Canton, Ohio
In Canada—Hamilton, Ontario

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PM²=Quality +Economy

in your electroplating of

HARD GOLD
HARD BRIGHT GOLD
SOFT GOLD
PLATINUM
RHODIUM
PALLADIUM

TECHNIC PM² (Precious Metal Plating Metallurgy) ensures Quality and Economy. For electroplating both conventional alloys and exotic alloys such as are required in electronics and atomics, Technic enables you to get predetermined results that are *exactly reproducible.* Our solutions and method give you rigid scientific control of performance and cost, eliminate wasteful deviation from strict standards.

CASE HISTORIES ON RECORD

Case histories illustrate the efficacy of Technic PM². Ask for the names of industrial leaders who lower cost and control quality with Technic precision electroplating.

TECHNIC SERVICE

Besides formulating scientifically correct solutions, we are equipped to install or to modernize all your requirements for precious metal electroplating. No Technic installation is checked out as complete until it achieves optimum performance. Send us your problems — old or new — for recommendations.

120-8

TECHNIC, INC.
39 Snow Street,
Providence, R. I.
JAckson 1-4200
Chicago Office—7001
North Clark Street
THE LARGEST ENTERPRISE OF ITS KIND IN THE WORLD

LIST NO. 147 ON INFO-COUPON PAGE 168

Solve
Inspection
Sorting
Demagnetizing
Problems
with
MAGNETIC ANALYSIS...

MULTI-METHOD EQUIPMENT

Electronic equipment for non-destructive production inspection of steel bars, wire rod, and tubing. Detects mechanical faults and variations in composition and physical properties. Average inspection speed — 120 ft. per minute.

SPECIAL EQUIPMENT

Electronic equipment for non-destructive production inspection of non-ferrous bars and tubing . . . as well as both non-magnetic stainless and high temperature steel bars and tubing — seamless or welded. Mechanical faults, variations in composition and physical properties are detected simultaneously. Average inspection speed — 200 ft. per minute.

WIRE ROPE EQUIPMENT

Electronic equipment for inspecting ferromagnetic wire ropes from 1/32" to 3" diameter. Detects broken, cross-over or missing wires, plus defective welds and deformations at production speeds up to several hundred feet per minute.

COMPARATORS AND METAL TESTERS

Electronic instruments for production sorting of both ferrous and non-ferrous materials and parts for variation in composition, structure and thickness of sheet and plating.

DEMAGNETIZERS

Electrical equipment for rapid and efficient demagnetizing of steel bars and tubing. When used with Magnetic Analysis Multi-Method Equipment, inspection and demagnetizing can be done in a single operation.

MAGNETISM DETECTORS

Inexpensive pocket meters for indicating residual magnetism in ferrous materials and parts.

TRADE MARK
"THE TEST TELLS"
For Details Write:
MAGNETIC ANALYSIS CORP.
42-44 Twelfth St., Long Island City 1, N. Y.

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ARC ETCH ANY METAL
OF ANY HARDNESS—Quickly—Easily
WITH THE
ACTOGRAP PEN

Only the ACTOGRAP metal etching pen has all of these features:
- Freedom from mechanical vibration
- Short, powerful, continuous arc—will etch hardest metals rapidly
- Does not heat up
- Light and small—can be used like a fountain pen
- Operates optionally on battery or conventional AC current
- Depth of etch can be regulated by an exclusive selection switch

only $49.50 with transformer

WRITE, WIRE, OR CALL FOR DETAILS

NEWAGE INDUSTRIES, INC
222 York Road
TUrner 4-8494
Jenkintown, Pa.

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Measures Nonmagnetic Coatings with ±5% ±.0001" accuracy

NEW pocket-size Thickness Gauge

ELCOMETER measures thickness of porcelain enamel, paints, platings, foils, glass, paper, plastics, and other nonmagnetic coatings quickly and accurately. Gauges flat or curved surfaces and hard-to-get-at spots easily. Needle locking device assures correct reading every time. Complete with tough leather case containing inner pocket for test strips. Weighs only 6 oz. Completely self-contained.

FREE TRIAL. Ask your purchasing agent to order an Elcometer on trial basis. Retail price, F.O.B. Cleveland.

ONLY
$75.00

FERRO
FERRO CORPORATION
4155 East 56th Street
Cleveland 5, Ohio

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HAWKRIDGE METALS CORPORATION

Producers and Sellers of
(VIRGIN)

TITANIUM POWDER

—20 to +200 mesh

Both HIGH PURITY and COMMERCIAL grades available.

North Hampton
New Hampshire

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TENSILKUT

Tensile and fatigue test specimens can be accurately machined from foil metals as light as .0005" or heavy .500" plate in less than two minutes. Machined edges are completely free of cold working and the specimen configurations are duplicated within ± .0005".

Tensilkut machines a wide range of metals including steel, aluminium, stainless steel, copper, titanium, uranium, lead, the super alloys and all plastic materials.

Tensilkut table and floor models are available with motors from ⅛ to 2½ HP. Write for our latest brochure.

Trade Mark Registered U.S. Patent Office
Patents Pending United States & Canada.

SIEBURG INDUSTRIES
INCORPORATED
HORSE PLAIN ROAD • NEW BRITAIN, CONN.

LIST NO. 131 ON INFO-COUPON PAGE 168

HARDNESS TESTING
SHORE SCLEROSCOPE

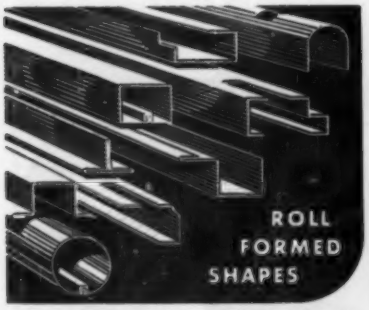
Pioneer American Standard Since 1907

Available in Model C-2 (illustrated), or Model D dial indicating with equivalent Brinell & Rockwell C Hardness Numbers. May be used freehand or mounted on bench clamp.

OVER 40,000 IN USE

SHORE INSTRUMENT & MFG. CO., INC.
90-35M Van Wyck Exp., Jamaica 35, N.Y.

LIST NO. 133 ON INFO-COUPON PAGE 168



Reduce your assembly problems and costs. Our shapes continuously formed, with high degree of accuracy, from ferrous or non-ferrous metals. Write for Catalog No. 1053.

ROLL FORMED PRODUCTS CO.

MAIN OFFICE AND PLANT
3761 OAKWOOD AVE. • YOUNGSTOWN, OHIO

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KENTRON
MICRO
HARDNESS TESTER

Applies 1 to 10,000 gram loads
Write for Bulletin

Kent Cliff Laboratories Div.
The Torsion Balance Company
CLIFTON NEW JERSEY

LIST NO. 53 ON INFO-COUPON PAGE 168

A CABLE SPLICED IN 10 SECONDS!

ERICO PRODUCTS, INC.
Complete Arc Welding Accessories
2070 E. 61st Place, Cleveland 3, Ohio
Write for Caddy Catalog

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THE NEW
DERMITRON

NON-DESTRUCTIVE COATING THICKNESS TESTER

FAST... ACCURATE NON-DESTRUCTIVE DIRECT-READING

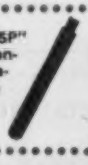
- Instantly measures the thickness of metallic and non-metallic coatings and films
- Based on eddy-current principles
- Enables measurements on small or otherwise inaccessible areas

This portable instrument for both laboratory and production use, gives fast, accurate and direct readings of virtually any coating on any base, including:

- Metal coatings (such as plating) on metal base (magnetic and non-magnetic)
- Non-metallic coatings (such as paint, anodizing, hard-coat, ceramic) on metal base
- Metal films (such as vacuum metalizing) on non-metallic base (plastics, ceramics)

MEASURING PROBES ARE AVAILABLE IN THE THREE TYPES SHOWN BELOW

NEW RIGHT-ANGLE PROBE model "RP" enables measurements in holes down to ½" I.D.



STANDARD PROBE model "SP" enables measurements on convex surfaces down to ⅛" radius of curvature and on concave surfaces down to 2" radius of curvature

MODIFIED STANDARD PROBE model "MP" enables measurements on concave surfaces down to ¼" radius of curvature

Each of the above probe types is available in 4 different thickness ranges—A, B, C and D, from thick to thin deposits.

Write for latest bulletins and questionnaire to help solve your thickness testing problems

UNIT PROCESS ASSEMBLIES, INC. UPA

LIST NO. 139 ON INFO-COUPON PAGE 168

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the GRIES
MICRO-REFLEX
HARDNESS TESTER

Loads: 10 to 3000 gram with CARL ZEISS Optical System

Measurement: to 0.0001 mm. . . . Observations on Ground Glass . . . Projection: to 0.001 mm. . . . Many Unique, Very Important Features.

INVESTIGATE!
Write for Bulletin No. A-16

GRIES INDUSTRIES, INC.
Testing Machines Division
NEW ROCHELLE 3 N.Y.

LIST NO. 135 ON INFO-COUPON PAGE 168

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make hardness tests
ANYWHERE
WITH THE
NEWAGE TESTER

- CLAMPS, JAWS & BASE PLATE ARE ELIMINATED
- NO CONVERSIONS OR CALCULATIONS
- TEST ANY SIZE, SHAPE OR TYPE METAL
- NO SKILL REQUIRED
- SCALE READINGS IN ROCKWELL & BRINELL
- ACCURACY GUARANTEED

Many thousands used by industry and government. Write, wire or call for additional details and prices.

NEWAGE INDUSTRIES, INC.
222 York Road *Jenkintown, Pennsylvania*
TUrner 4-6091 *Dept. MP*

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***Leitz* MINILOAD TESTER**
FOR VICKERS AND KNOOP HARDNESS

STANDARD HARDNESS TESTERS for ROCKWELL and BRINELL TESTS also available

Request Catalog 72-1

OPTO-METRIC TOOLS, INC.
137 MP VARICK STREET, NEW YORK 13.

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STAR STAINLESS SCREW CO.

CORROSION RESISTANT

647 Union Blvd., Paterson 2, N. J.
Telephone: CLifford 6-2300
Direct N.Y. 'phone Wisconsin 7-9041
Direct Phila. 'phone WAlnut 5-3660

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Whitelight MAGNESIUM

your comprehensive independent mill source of magnesium alloy . . .

ALLOYS
AZ10
AZ31
AZ51
AZ61
AZ81
ZK60
ZK30
M-1
ZK-20
Anodes

RODS ¼" dia. to 6½" dia.
BARS, STRIPS .022" min. to 7½" max.
SOLID SHAPES .022" min. to 6½" circle
TUBING ¼" O.D. to 8" O.D.
HOLLOW SHAPES ¼" to 6½" circle
PLATE & SHEET .032" to 3" thick

WHITELIGHT MAGNESIUM

WHITE METAL ROLLING & STAMPING CORP.
82 Moultrie Street, Brooklyn 22, N.Y.
Factories: Brooklyn, N.Y. • Warsaw, Ind.

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Ask the Man Who KNOWS Stainless Welding . . .

Call Mr. Electrode . . . His years of experience and leadership in providing the correct—

Stainless and Heat Resistant Arc Welding Electrodes

—place a trusted guarantee back of your welding operations.

Automatic Welding . . .
• All Analyses
• Coated, Straightened
• Cut • Coiled and Spooled

MAURATH, INC.
21830 Miles Avenue • North Randall 22, Ohio
Phone: MOntrose 2-6100

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EVERY PITTSBURGH INDUCTION HEATING FURNACE installation is backed by these outstanding features:

- Pre-testing of Unit
- One-Year Warranty
- Maximum Safety
- Labor and Space Savings
- Greater Margin of Profit

PIH

Consult a PIH Engineer for complete information on a wide range of applications for optimum heating of all metals for numerous metal working operations such as: forging, rolling, annealing, extrusion, and others.

Write for detailed brochure with frequency chart

PITTSBURGH INDUCTION HEATING COMPANY INCORPORATED
3945 Middleboro Road, Pittsburgh 34, Pa. Phone LO. 3-6020

LIST NO. 181 ON INFO-COUPON BELOW

READERS' INFO-COUPON SERVICE, METAL PROGRESS
7301 Euclid Avenue, Cleveland 3, Ohio

Please send further information, as checked at the right, on the advertisements in the Bulletin Board with numbers I have listed below—

(Bulletin Board Item Number)	(Please check) Send Catalog or Engineering Data	Send Price Info	Nearest Source of Supply
	☐	☐	☐
	☐	☐	☐
	☐	☐	☐
	☐	☐	☐
	☐	☐	☐

Your Name..... Title.....
Company.....
Street.....
City..... Zone..... State.....

hydrogen gas

..... new packaged plant makes it in quantities up to 5000 scfh at tremendous savings

1000 scfh hydrogen generator undergoing tests at company's Lorain, Ohio plant.

Here's 99+purity hydrogen gas in quantities from 250 scfh to 5000 scfh as low as 55 cents per 1000 cubic feet.

This amazing packaged plant developed and test proved comes complete on a common base ready to connect utilities and begin continuous operation. It has all the standard Gas Atmospheres' features such as push-button purge starting, fully automatic controls, proven "fail safe" safety devices, and automatic raw material measuring and flow equipment.

If you are now buying hydrogen gas or dissociated ammonia you'll want to know more about this latest development by the nation's largest organization devoted exclusively to the production of controlled atmospheres for industrial application.

ORIGINATORS AND LEADING PRODUCERS

gas Atmospheres, inc

equipment for producing industrial gases

20011 WEST LAKE ROAD CLEVELAND 16, OHIO

OF PACKAGED GAS GENERATION SYSTEMS

Fast-accurate

SULFUR

analysis

IRON STEEL PETROLEUM PRODUCTS ORGANIC CHEMICALS STAINLESS ALLOYS COAL WOOD NON-FERROUS METALS MINERALS COKE

with a

DIETERT-DETROIT

Sulfur Determinator

The Dietert-Detroit Sulfur Determinator features an extremely simple direct-reading burette. No involved measuring or computing. Provides fast accurate analysis of sulfur content in scores of materials. Low cost, durable, easily maintained. Widely used in company laboratories and institutions of every description for over 18 years.

Dietert-Detroit Sulfur Determinator No. 3104, with combustion Furnace.

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Uses of Titanium . . .

(Starts on p. 109)

yet, are the 14% Cr martensitic turbine blade steels and the hot work die steels. Heat treated 4340 Ni-Cr-Mo engineering alloy steel is superior to annealed titanium on a strength-weight basis only at temperatures up to 400° F.

These facts are summarized in Table II, p. 111. It should be noted that data showing the mechanical properties of metals at working temperatures are rarely sufficient for an intelligent choice. Expected life at maximum stress and temperature, fabrication problems and costs also are important factors. Even so, at current and near-future stages of development, titanium sheet alloys have a better strength-weight ratio than steels in parts working in tension and nonbuckling compression up to 800° F. Their superiority is much more marked where buckling must be considered; the optimum stress level for minimum weight then tends to be less than the compressive yield strength, particularly in lightly loaded structures, and this favors the lighter metal even though is may not be quite so strong as the alloy steels.

Sandwich construction is an attractive means of achieving an optimum resistance to buckling. In manufacturing these composite structures, welding or brazing is a factor as well as availability of sheet or foil of suitable gages and sizes. Developments in these lines are further along in steel than they are in titanium.

For the time being, steel is avail-

Table III – Titanium for U.S. Air Forces, 1957

Designation	Manufacturer	Mill Shapes	Usage
Fighters			
F-100	North American	1300 lb.	After fuselage
F-101	McDonnell	1400	After fuselage
F-102A	Convair	1500	After fuselage, engine shrouds, wing spar attachment
F-104B	Lockheed	260	Tail cone
F-105	Republic	260	Tail cone, dive brake
Cargo Ship			
C-130	Lockheed	1100	Engine nacelles
Bombers			
B-52D	Boeing	1400	Engine nacelles
B-52D (M.I.)	Boeing	4600	Engine nacelles, fasteners, forgings
B-58	Convair	300*	Fasteners

*Plus a possible 5000 lb. in honeycomb structure, forgings and sheet.

Table IV – Projected Consumption of Titanium, Short Tons*

User	Selling Price of Mill Products	
	$2 to $3 per lb.	$1 to $1.50 per lb.
Military aircraft	20,000 to 30,000	20,000 to 30,000
Commercial aircraft	2,000 to 3,000	3,000 to 4,000
Chemical and other process equipment	15,000 to 20,000	20,000 to 25,000
Marine	1,000 to 2,000	2,000 to 3,000
Ordnance and other military	8,000 to 10,000	10,000 to 15,000
Automobile (passenger)	2,000 to 3,000	125,000 to 150,000
Trucks and buses	10,000 to 15,000	30,000 to 45,000
Railroad	1,000 to 2,000	3,000 to 4,000
Other	3,000 to 4,000	11,000 to 19,000
Total	62,000 to 89,000	224,000 to 295,000

*The $2 to $3 price is the eventual minimum from Kroll process sponge, and consumption is estimated by Titanium Metallurgical Laboratory of Battelle Memorial Institute. The $1 to $1.50 price is the eventual minimum from some new reduction process, and consumption is estimated by D. F. Porter of Rutgers University.

review of metal literature

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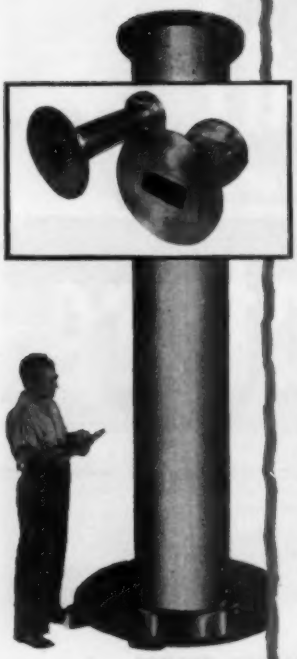

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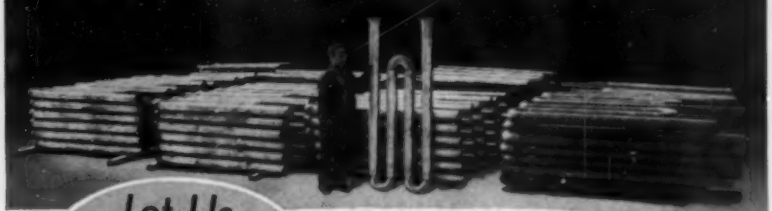

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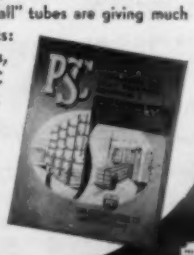

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Uses of Titanium . . .

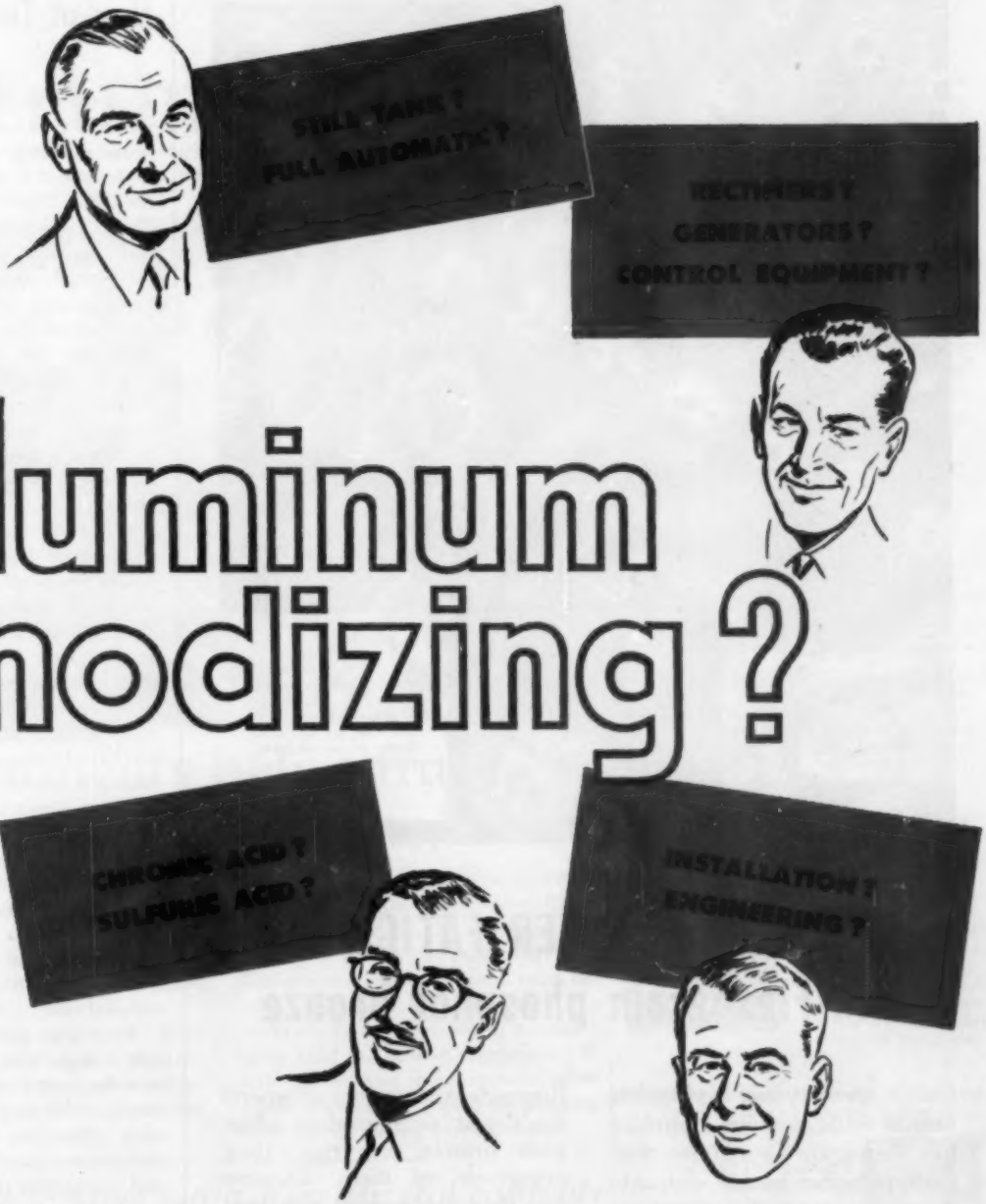
able in larger, wider and thinner sheets; this eliminates unnecessary joints. Unless titanium alloys become available in a similar variety of shapes and sizes and unless its fabricating problems, including welding (or brazing), are worked out satisfactorily, titanium will have to yield to steel in many applications for which it would otherwise probably be preferred.

On the other hand, titanium often has an advantage where the minimum available gage of steel is thicker than required for strength alone, or where a wide flange must be provided merely for attaching another part. Where corrosion is a factor, titanium is superior to any commercial alloy of iron in almost any circumstance.

The cost differential is a serious handicap. Titanium costs about ten times as much per pound as high-strength stainless steels – even on a volume basis, nearly six times as much. This added cost of titanium has to be abundantly justified by superior performance before cost-conscious designers will recommend its use.

Costs of Aircraft – For the reasons sketched above, the principal market for titanium will probably be in aviation where weight saving is at a premium. Few experts agree as to how much can be paid to save a pound of weight in airframe or engine, because for every pound saved in an engine, for example, 3 to 10 lb. more can be saved in the final weight of the airplane. Wing and tail area, fuselage, horsepower, fuel and fuselage size are all calculated on the basis of starting weight. Consequently, titanium can rarely be substituted for steel, economically, merely by building a part of the new alloy, and only since 1957 has titanium been incorporated in the original design. For example, Canadair's new CL-28, a maritime patrol bomber for the Royal Canadian Air Force, uses 2700 lb. of titanium in the skin, bulkheads and firewall sections of four-engine nacelles, saving 900 lb. in over-all weight. It is believed that each new commercial jet transport may use as much as one ton of titanium sheet and extrusions plus some titanium fasteners.

In civilian and some military



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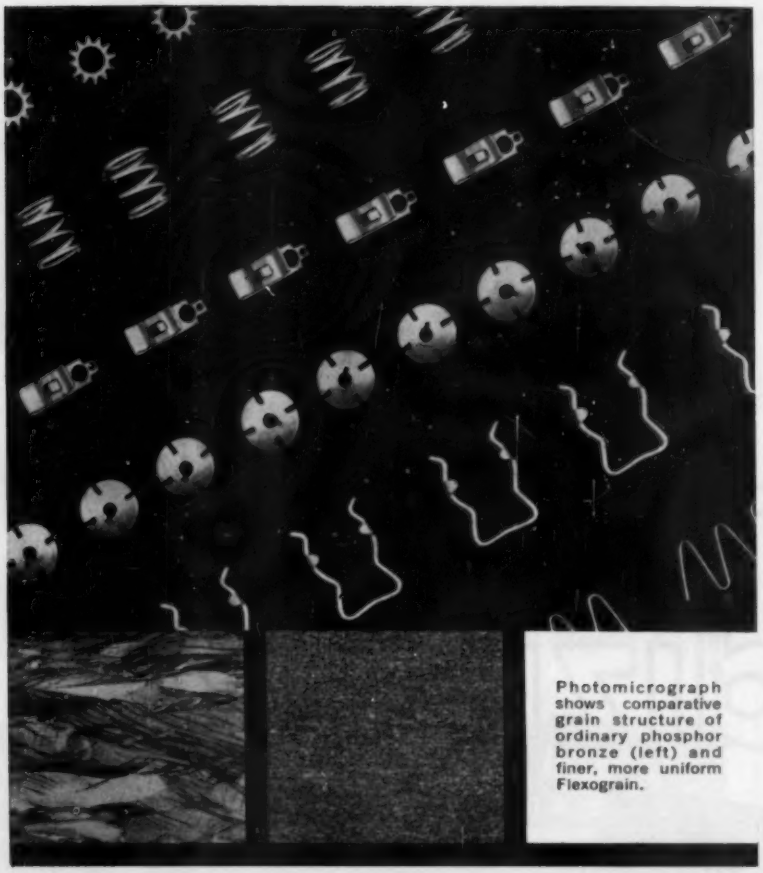

Photomicrograph shows comparative grain structure of ordinary phosphor bronze (left) and finer, more uniform Flexograin.

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Uses of Titanium . . .

planes, the additional cost of titanium must be justified by economic and safety factors, but in other types of fast and long-range military planes *performance* is the dominant reason for using more expensive material. These considerations did not disturb the rosy estimates of requirements made in the early days of the Government's program. One witness before a Senate Committee in 1954 said that $30 could be paid to save a pound of weight even in commercial aircraft. John Garrett, chairman of the Steering Group, supporting the 35,000-ton figure of annual need for sponge, stated that all estimates were based on the current price of titanium and that "if its price comes down, the requirements would be very much higher . . . As far as airplanes go", he added, "I think price was considered not to be a factor. But when you get to ships or tank armor or something that would make an individual piece cost many millions of dollars more, then you have to stop and consider price." Arthur S. Flemming, director of the Office of Defense Mobilization, said late in 1955 that "The Department of Defense should make every effort to expand the use of titanium in military equipment on a production basis despite its present high cost. This will permit rapid advance in fabrication technology and lead to reduced cost."

There is no question, however, but that designers of American aircraft were hesitant to start designing with titanium because of some of the early difficulties with brittle sheet and because they were not sure that mill production would be available by the time the aircraft were being built. Some of these "growing pains" may be briefly described.

Aircraft Experience

Owing to the many problems with a new metal, a great deal of material was spoiled. Westinghouse's Gas Turbine Div. had to throw out 200,000 lb. of metal because it picked up so much carbon in melting that it could not be machined. Another lot of unalloyed titanium delivered to Douglas Aircraft was so high in hydrogen it could not be formed and it tore easily. Other troubles were traced back to variations from heat to

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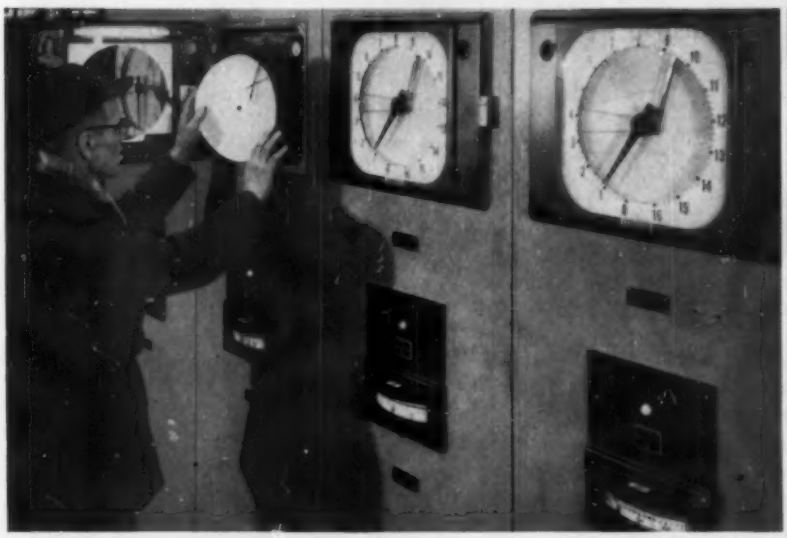


Instruments help turn out casting cores at 7 tons/hour

Engine blocks for Ford and Mercury automobiles are cast with strictest attention to accuracy and structural quality at the Cleveland foundry of the Ford Motor Company, Brookpark, Ohio, just outside Cleveland.

Yet these rigorous requirements must not impede the smooth flow of the production line. That's one reason Ford installed this battery of Bristol Dynamaster* instruments.

Another: In the early days, core baking used to be an all-night process. Cores were of fine quality, but the output was too low for present-day production lines. The new core baking method turns out top quality cores at the rate of 7 tons an hour. Bristol instruments automatically hold the baking temperature to 450° ± 5°F. And, in emergencies, allow faster processing by raising the temperatures and increasing conveyor speed.

First oxygen steel plant uses Bristol controls

Bristol round chart Dynamaster* instruments (top) and Bristol Metagraphic miniatures (center row) play a big part in controlling oxygen steel-making at Dominion Foundries & Steel, Ltd.

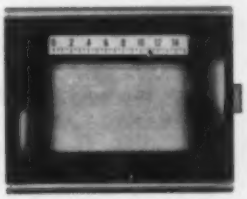
When Dominion Foundries & Steel, Ltd. (Dofasco), at Hamilton, Ontario, first introduced this method of steel-making to the North American Continent, they chose Bristol instruments and controls (above) to supervise the most critical steps in the process.

These include oxygen pressure and flow (current rate and total), lance position, lance cooling water temperature, flow, and pressure as well as various other temperatures.

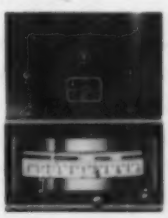
The big advantage of oxygen steel-making is the lower original investment in equipment. Only about 50% of the equipment costs of competitive processes is required and operating costs are no higher, with equal or better product.

Furnace, oven, dryer— Bristol controls them all

Whatever your industrial heating application, you can find a Bristol instrument or instrument system to provide precision indication, recording or automatic control. The following instruments, in almost innumerable variations, are typical of the truly complete Bristol instrument line.

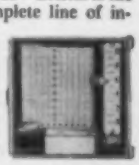


Bristol's Dynamaster* Potentiometer Pyrometers come in round or strip chart models, provide electronic recording, indication, and electric or pneumatic control, including high-low contact, proportional, time-program and many combinations. The outstanding instrument for maximum precision.



Bristol Millivoltmeter Pyrometers. Both indicating and controlling models available. Controlling models utilize unique Bristol Free-Vane* principle that completely eliminates relay "chatter" or "flutter." High-low contact and proportional models available in a wide variety of combinations.

Bristol Miniature Instruments – Bristol is the only company offering a complete line of instruments in both miniature *and* full-size for all recording, indicating and control applications, both electronic and pneumatic. True plug-in construction. Ideal where panel space must be conserved.



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Uses of Titanium . . .

heat and lack of uniformity, even within a single sheet, in chemistry, mechanical properties, surface finish and gage. Even with uniform material of proper quality, rejection rates were high at most factories until necessary experience could be acquired.

Late in 1954, an epidemic of delayed cracking in parts formed from 8% Mn alloy sheet raised doubts as to whether it could be used safely in aircraft. These difficulties were corrected but not before other materials were substituted for titanium in several prospective applications.

Actual failures in service after passing factory inspection have been astonishingly few. Some compressor parts in Pratt & Whitney and General Electric jet engines cracked on spin tests and engine runs. These failures were traced to hydrogen embrittlement and were eliminated by vacuum annealing. Many fabricators, however, had already introduced vacuum annealing, and the titanium industry was about ready to adopt it generally when these difficulties were encountered.

It did not take long to learn that titanium was a metal with a character of its own. When special tools and procedures were adopted, production of titanium parts became routine and spoilage and shop rejects at aircraft plants declined.

Military Aircraft – Current consumption of titanium is principally in the compressor assembly ahead of the combustion chamber in Pratt & Whitney J-57 and J-75 jet engines. Temperature in service is from 200 to 800° F., which is the most efficient range for titanium. The net weight of the titanium parts in these two engines is about 300 to 600 lb. However, to allow for manufacturing losses and for spare parts, requirements are for 1400 lb. of mill shapes for the J-57-19 engine, 3700 lb. of mill shapes for J-57 (series C) and 3000 lb. for J-75. In the combustion chamber and most parts of the engine aft of the compressor, the temperatures are too high for titanium. Since the B-52 bomber uses eight of the J-57 (series C) engines, titanium's use in this unit has dominated the requirements and the "stretch-out" in delivery of these bombers was the prime cause of the

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You design for consistent performance. Production demands consistent fabrication properties. You have to have both.

If high temperature alloys don't give you both, there is usually just one reason—lack of uniformity. And you can trace it right back to the original ingot your alloy came from.

Variation in toughness or alloy content between centerline and material nearer the surface of an ingot cannot be removed by any amount of working. Troubles pass from ingot to bar to rod to wire—to you.

MEL-TROL stops this kind of trouble before it can start. Throughout the steelmaking process, the newest and most accurate quality controls guard MEL-TROL alloys. Steel is poured into the new, *Carpenter*-patented ingot mold that produces greater uniformity in the ingot than any other method now used in steelmaking.

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Webb Wire Division, New Brunswick, N. J.

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- √ ABRASION RESISTANCE
- √ CORROSION RESISTANCE
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Unitcast produces a complete range of cast steels, from plain carbon grades through the low alloy ranges—with subsequent heat treat service. Listed below are six basic steels produced by Unitcast. Variations or special steels on request.

CARBON STEEL CASTINGS

TYPE OF CASTING	PHYSICAL PROPERTIES					GENERAL CHARACTERISTICS
	Tensile Strength p.s.i.	Yield Point p.s.i.	Elongation in 2"	Reduction of Area	Brinell Hardness	
LOW CARBON (Grade B Soft)	60,000	30,000	25%	40%	120-140	Comparable to SAE 1020. Ideal for carburizing purposes. Weldability excellent. High ductility.
MEDIUM CARBON (Grade B Medium)	70,000 (Min.)	38,000 (Min.)	24% (Min.)	36%	140-170	Comparable to SAE 1025. Good machinability. Above average physical properties. Weldability excellent. Good ductility.
MEDIUM HIGH CARBON (Grade B Medium High)	80,000	43,000	18%	30%	170-190	Comparable to ASTM-A-148-46T 80—40. Slightly higher carbon than "Medium" grade with higher tensile properties. Decreased ductility. Water quench will increase hardness. Pre-heating and post-heating recommended for welding.
HIGH CARBON (Grade B High)	85,000	53,000	17%	25%	179-217	Comparable to SAE 1045. Attained higher tensile properties result in slightly less ductility. Suitable for high surface hardness. Welding difficult unless pre-heated and post-heated.

ALLOY STEEL CASTINGS

PHYSICAL PROPERTIES* T-LOY 34	HEAT TREATMENT			GENERAL CHARACTERISTICS
	Normalized Drawn	Oil Quenched 1200° F Drawn	Oil Quenched 900° F Drawn	
Tensile Strength p.s.i.	90,000	105,000	150,000	Comparable to SAE or AISI 8632. Oil quench produces excellent tensile strength properties ranging to 150,000 p.s.i., coupled with high ductility, wear resistance and immunity to temperature changes. Specific areas may be flame or induction hardened.
Yield Point p.s.i.	60,000	85,000	125,000	
Elongation in 2"	20%	17.0%	10.0%	
Reduction of Area	40%	35.0%	25.0%	
Brinnell Hardness	187-217	217-246	305-342	
T-LOY 42				
Tensile Strength p.s.i.	100,000	120,000	175,000	Superior to SAE or AISI 8640. Recommended when high strength and hardness are desired in the normalized and drawn condition. Deeper hardening obtained by oil quench and draw with tensile up to 175,000 p.s.i. High degree of hardness will be attained with spot or flame and air cooling. Water quench not recommended.
Yield Point p.s.i.	75,000	100,000	145,000	
Elongation in 2"	12%	12%	10%	
Reduction of Area	25%	28%	25%	
Brinell Hardness	217-246	250-280	350-380	

* Physical properties based on a .505" test bar turned from a standard 1½" cast test coupon.

NOTE: Certified copies of complete test records—plus special test reports on each heat of steel—are provided to Unitcast customers on request.

Let Unitcast's engineers help you select the *right* castings for your requirements. Write or call today for detailed specification sheets. No obligation, of course!

Unitcast SPECIFICATION STEEL CASTINGS

UNITCAST CORPORATION • Toledo 9, Ohio

Uses of Titanium . . .

recent slump in production. (The J-75 engine is now used only in fighter planes which have only one engine.)

Only 10 to 20% of the titanium required by the Air Force now goes into airframes. A list of the designs, manufacturers and consumption is contained in Table III (p.170), to which may be appended the note that neither the Douglas cargo ship C-133 or the bomber WB-66 uses more than nominal amounts.

In 1953 the Aircraft Industries of America estimated that 2% of the total airframe weight might be unalloyed, and another 3% in alloyed titanium in the near future, and that this might rise eventually to 3.5% and 30% respectively. Battelle Memorial Institute made a survey in 1957 which indicated that future military planes could advantageously use 10% of airframe weight as titanium, and that up to 50% might be used "if alloys with room-temperature yield strengths of over 150,000 psi. and correspondingly high elevated-temperature strength become available". While the titanium alloys used in airframes have hitherto been of the 110,000-psi. min. yield class, Table II shows that candidate alloys for the Sheet Rolling Alloy Program may develop strengths in the high range set by the target. Annual airframe production in the U.S. in 1956 totaled 45,000 tons for military planes and 10,000 tons for civilian. (Individually, they vary from as little as 7000 lb. for a small fighter plane to 100,000 lb. for a big transport.) These figures tend to reaffirm earlier expectations that airplane factories will be needing 30,000 tons or more of titanium within a very few years.

At flying speeds up to about twice the speed of sound, airplane skin temperatures are not likely to exceed 200° F. Accordingly, most of the frame of a Mach 2 airplane, other than the parts affected by engine heat, would still be made of aluminum. At Mach 3 or higher, however, the leading edges and certain other parts of the airframe would get too hot for aluminum but would operate in the most efficient temperature for titanium. Titanium also appears to be the best material for many parts of gas turbines driving

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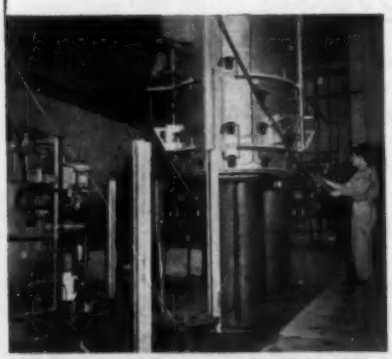

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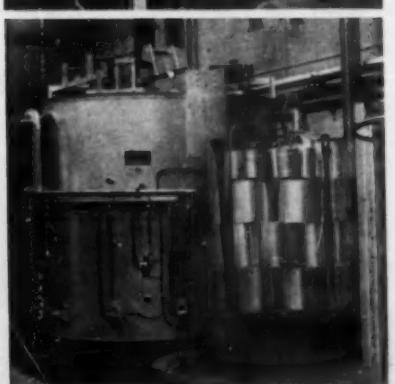

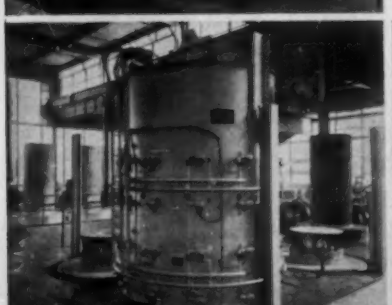

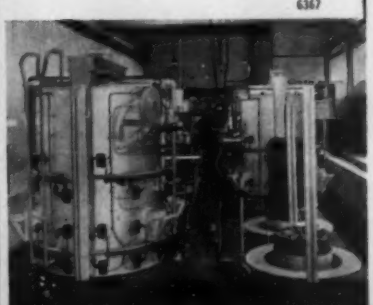

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Uses of Titanium . . .

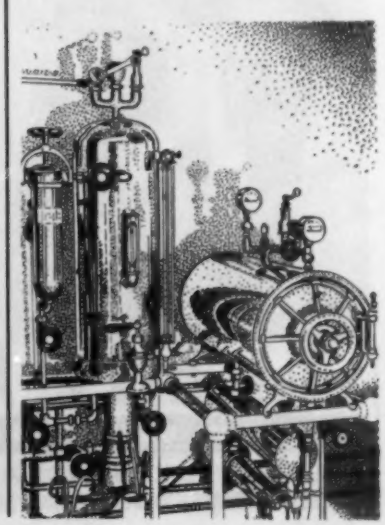
aircraft up to Mach 3.5 – about the top speed now considered for atmospheric flight.

Usage in airframes may also be extended by the new heat treated sheet alloys with a higher range of efficient temperatures, thus having a wider strength-weight advantage over aluminum on the low-temperature side and over steel on the high-temperature side.

The decision as to whether to use titanium or some other metal for a given component of an engine or airframe is made at the manufacturing company's drawing board. The Air Force purchases airplanes on the basis of performance; it does not specify materials. Consequently, the fact that an engine manufacturer can produce an engine that meets specifications without using titanium does not imply that he could not build a better engine if he did.

Uses by the Army

Early plans included the expectation that fairly large tonnages of titanium would be used in Army Ordnance, but current usage is quite small. It is obviously desirable for construction of equipment to be carried by the foot soldier or transported by air. In ballistic applications, titanium offers a 25% advantage over steel, weight for weight. Rust resistance may also be a factor, but most potential applications are now prevented by high cost of the raw material. *(Continued on p. 182)*



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Uses of Titanium . . .

Navy uses have been largely confined to carrier-based fighter planes powered by J-57 engines and which also use titanium in the airframe where corrosion resistance is of special importance. Were it not for its high cost, titanium would probably be used on shipboard wherever bare metal is exposed to sea water. Naval Ordnance, like Army Ordnance, considers that the advantages of using titanium in most armor applications do not warrant the additional cost.

The Future – So long as the Armed Services account for over 95% of the actual consumption of titanium, estimates of requirements by the Department of Defense set the maximum pace for the industry. For several years the military expressed its desire to use many times as much titanium as the industry was equipped to supply in suitable shapes and sizes. Late in 1956, the industry was told the bad news that the titanium version of the J-57 engine would not be used in the four-engine KC-135 tankers because of its cost and of doubts that deliveries of titanium mill products could keep pace with the production schedule. In May 1957 the requirements were again revised sharply downward to match the slower deliveries of the intercontinental bombers during the Government's current fiscal year. The industry had been built up in anticipation of an ingot rate of 30,000 tons annually by the end of 1957, but estimates of requirements by the Air Force call for but a fraction of existing capacity in 1958 and even less in 1959.

The immediate impact on the industry's sales was even more serious than the figures show. Not only were the "pipe lines" from mine to mill flowing at earlier projected rates but subcontractors had large inventories of finished parts as well as of raw stock. Since the normal lead time between receipt of raw material and delivery of a finished airplane is about nine months, a company with even normal stocks of metal on hand and in process might postpone new buying for many months after a cutback of 50% or more.

Producers of mill products have indicated that their main concern lies in the resultant slowdown in research and development, loss of competent personnel, and higher costs which tend to postpone price reductions which might stimulate wider markets. Nevertheless, a change in the opposite direction is always possible. Therefore, even if we seem to be at a place where *price* is the main deterrent to use, and price cannot be lowered substantially without large increase in output, this author would like to end with presentation of Table IV on p. 170, showing estimated consumption of titanium when mill products made from Kroll process metal can be sold for $2 to $3 per lb., and when metal from new (possibly electrolytic) methods will enable mill products to be sold for half that much.

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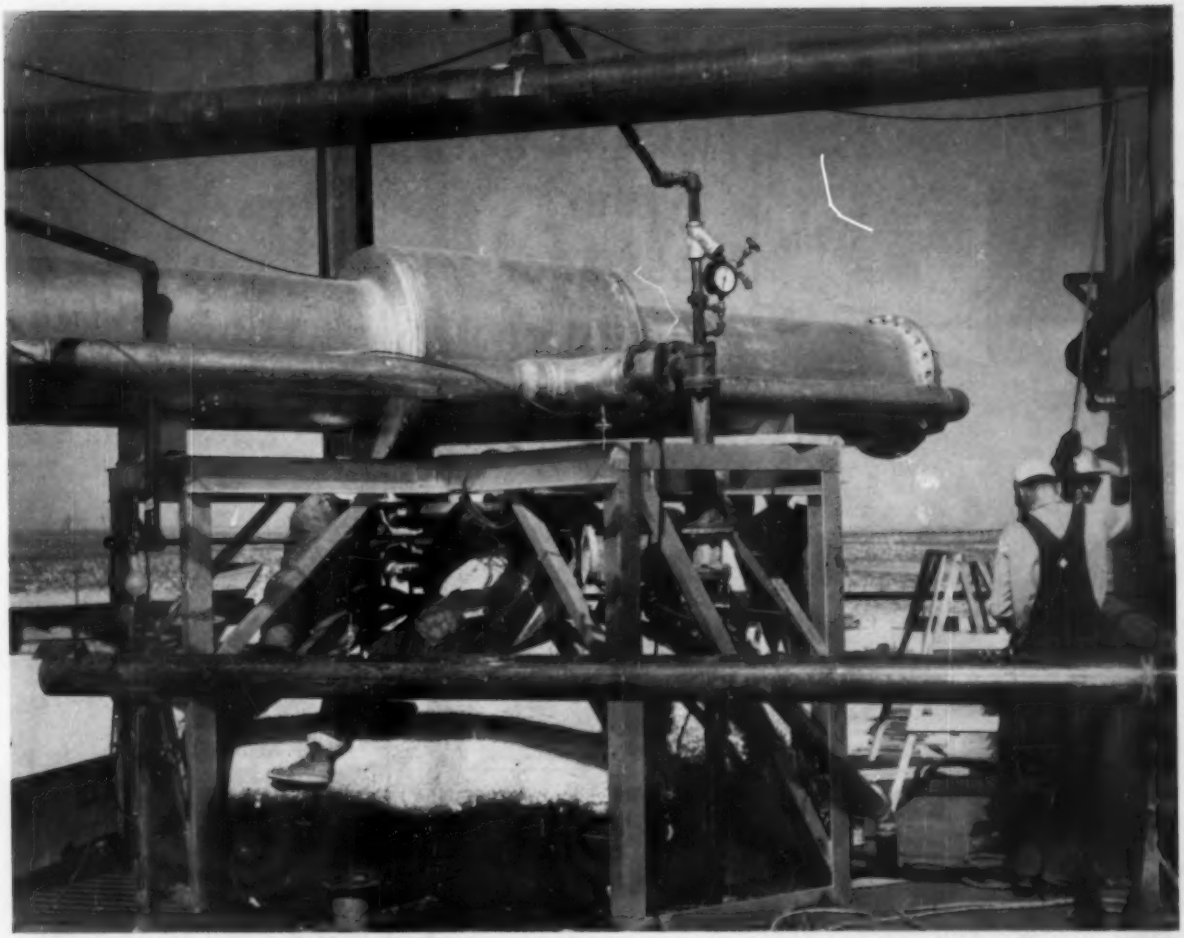

Erecting a crystallizer at a potash refinery in the southwest. This is one of seven crystallizers that were shop- and field-fabricated, then field-assembled by welding. They were not stress-relieved or heat-treated. There has been no stress corrosion cracking in the nine months these units have been in service at the potash refinery.

NEW Ampco Metal Grade 8 stops stress corrosion cracking!

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3. Readily weld with any electric welding process! A. No pre-heat. B. No post-heat. C. No hot-short cracking!

At one major oil refinery, field-assembled piping of Ampco Metal Grade 8 has handled hot sulphuric-acid sludge for a year and a half without stress-cracking. Driers in a paper mill have handled 350° F steam at 125-lbs. pressure for more than a year without stress-cracking.

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Powder Metallurgy . . .

(Starts on p. 95)

in hydrogen at 625° C. (1150° F.). The main impurity in the powder is 0.1% iron, apart from gases which are removed on sintering.

L. R. Williams found the powder, as produced, to be unsatisfactory for compacting and sintering, since the large volume of gases evolved, coupled with rapid surface sintering, resulted in internal voids and surface blisters. By mixing with a proportion of coarse powder prepared by crushing hydrogen-embrittled scrap, this was corrected. Compacts of this mixture are heated by resistance or induced currents in a vacuum of −50.01 microns, hydrogen being evolved up to 1000° C. (1800° F.), then carbon monoxide up to 1650° C. (3000° F.) and oxygen and nitrogen above 1900° C. (3450° F.). (These results are similar to those obtained by R. H. Myers about 10 years ago for tantalum sintering.)

Final sintering temperature is 2300° C. (4200° F.) for 2 to 10 hr. The sintered bars may then be cold worked 25 to 30%, reheated to 2300° C. in vacuo for a short time, then cooled, the ends cropped, and the material — now ductile — may be rolled or swaged into bar or sheet, suitable for conventional forming.

Vanadium

Methods for producing vanadium powder by direct reduction of its oxides have been explored both in America and in the United Kingdom. Recently a method involving the chloride route, similar to that described above, has been devised at the Culcheth laboratories. In this process ferrovanadium is burnt in chlorine at above 1000° C. (1800° F.) and the mixed chlorides passed through a "cold trap" at about 200° C. to condense the iron and other chlorides, but allow passage of the VCl_4. This is refluxed under argon to form VCl_3, a compound of low vapor pressure, followed by vacuum treatment at 50° C. to remove the volatile $VOCl_3$ and $SiCl_4$ — the principal contaminants. Vanadium trichloride is reduced to metal powder by hydrogen, preferably using fluidized bed technique to increase gaseous diffusion rates. The vanadium is in the form of lightly sin-

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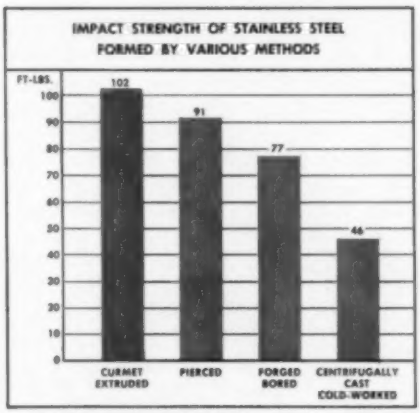
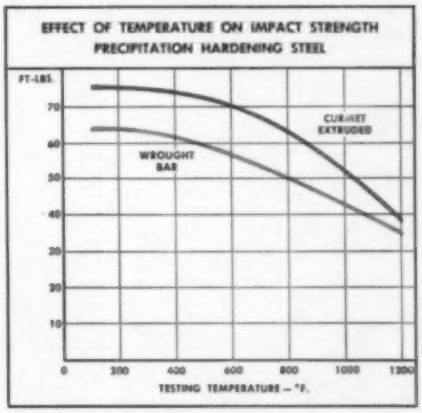
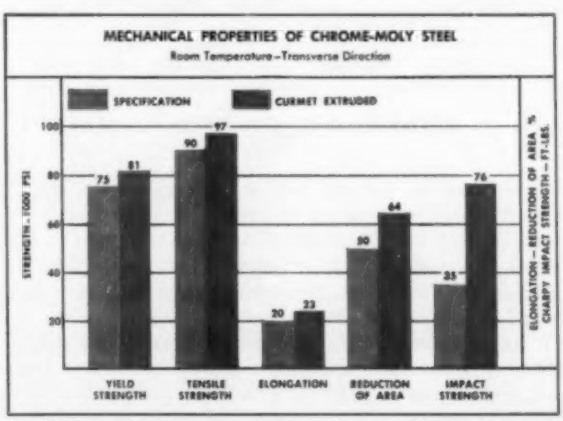


Impact strengths (Charpy) at 300° F. below zero. Curmet extruded Grade 304 stainless steel shows strength from 13% to 120% higher than the same alloy processed by other methods. Improvement in impact strength is consistent up to 1200° F.



Impact resistance of strength-at-high-temperature steels (A-286 in this case) is substantially greater when Curmet processed. The Curmet extrusion tests consistently 10 ft.-lbs. better than the usual wrought product.



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Work which has appeared in previous metallographic exhibits held by the American Society for Metals is unacceptable.

Photographic prints should be mounted on stiff cardboard, extending no more than 3 in. beyond edge of print in any direction; maximum dimensions 14 by 18 in. (35 by 45 cm.). Heavy, solid frames are unacceptable.

Entries should carry a label on the *face of the mount* giving:

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Any special information as desired.

The name, company affiliation and postal address of the exhibitor should be placed on the *back of the mount* together with a request for return of the exhibit if so desired.

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Class 5. Copper, nickel, zinc, lead and their alloys.

Class 6. Uranium, plutonium, thorium, zirconium and reactor fuel and control elements.

Class 7. Metals and alloys not otherwise classified.

Class 8. Series showing transitions or changes during processing.

Class 9. Welds and other joining methods.

Class 10. Surface coatings and surface phenomena.

Class 11. Slags, inclusions, refractories, cermets and aggregates.

Class 12. Electron micrographs.

Class 13. Results by unconventional techniques.

Class 14. Color prints in any of the above classes. (No transparencies accepted.)

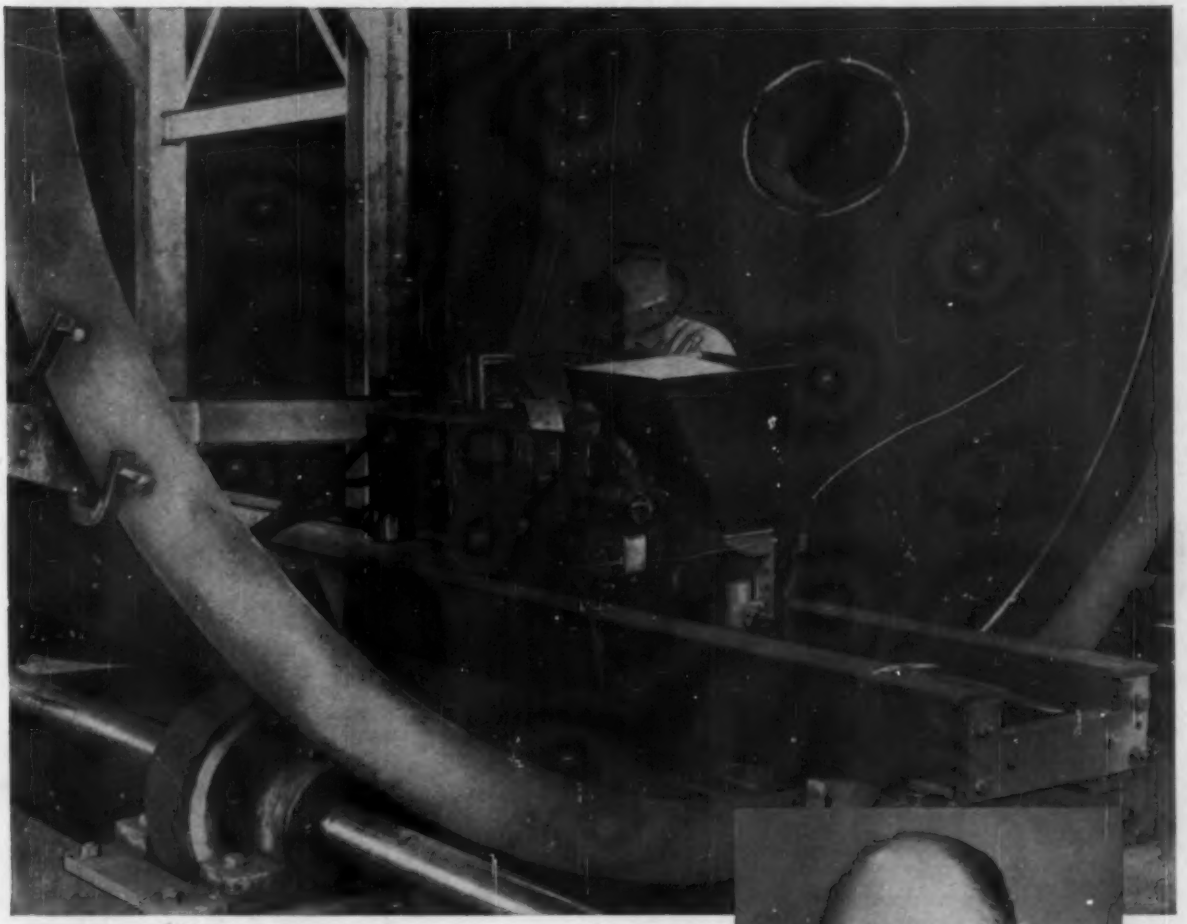
AWARDS AND OTHER INFORMATION

A committee of judges will be appointed by the Metal Congress management which will award a First Prize (a medal and blue ribbon) to the best in each classification. Honorable Mentions will also be awarded (with appropriate medals) to other photographs which in the opinion of the judges closely approach the winner in excellence. A Grand Prize, in the form of an engrossed certificate and a money award of $500 from the Adolph I. Buehler Endowment will also be awarded the exhibitor whose work is judged best in the show, and his exhibit shall become the property of the American Society for Metals for preservation and display in the Society's national headquarters in Cleveland.

All prize-winning photographs will be retained by the Society for one year and placed in a traveling exhibit to the various Chapters.

40th NATIONAL METAL CONGRESS & EXPOSITION

CLEVELAND PUBLIC AUDITORIUM — — — OCTOBER 27 THRU 31, 1958



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Powder Metallurgy . . .

tered agglomerates which are broken down to −300 mesh, and compacted and sintered at 1750° C. (3200° F.) in high vacuum. The resulting metal is ductile, has a grain size of about 500 microns, is relatively free from inclusions, and has a Vickers hardness of 120 to 150.

Beryllium

So much important work has been done on beryllium in recent years that a third article in this series is warranted. Very interesting results have been achieved by compacting the powder at about 800° C. (1475° F.), midway between "warm pressing" and "hot pressing", and pressures up to 20 tons per sq.in. Fine-grained beryllium almost free of porosity is the result.

High-Temperature Materials

Sintered alloys of the Vitallium type have been developed by the General Electric Co. at Wembley, having unusually low porosity (about 1%), a property which is necessary for good high-temperature strength. An alloy containing 64% Co, 30% Cr, and 6% W was prepared by sintering mixed powders at 1300° C. (2375° F.) in pure dry hydrogen for 12 hr. The chromium was added as a 50-50 Co-Cr alloy powder, and by careful control of particle size and size distribution, alloys of low porosity were produced.

An important advantage of the powder metallurgy technique for these alloys is the possibility of fabricating articles such as gas turbine blades with internal cooling channels by incorporating in the powder compacts cadmium wires which are volatilized prior to sintering.

Oxidized Magnesium Powder

The successful production of S.A.P. (aluminum containing dispersed oxide, and possessing exceptional high-temperature strength) naturally stimulated experimental work on the magnesium analogue S.M.P., which would have a considerably lower density, as well as lower absorption of thermal neutrons. Crushed magnesium (−200 mesh) was used. It was heated at 500° C. (925° F.) in oxygen at a pressure of about 1 mm. Hg to increase its oxygen content to about

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Powder Metallurgy . . .

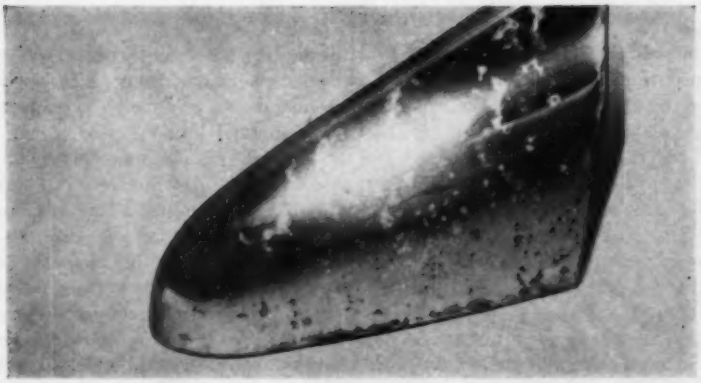
5% – this method being used in the hope of forming "oxygen deficient" magnesia surfaces which would bond more readily to the metal particles. The powder so treated was black, but electron diffraction patterns showed well-defined lines corresponding to MgO.

This powder was extruded from a 1-in. diameter compact to 0.25-in. round rod at 400° C. (825° F.) at about 0.1 in. per sec. The extruded rod was creep tested under an axial load of 1700 psi. at 350° C., the resulting creep rate being 2×10^{-7} per hr. (At this temperature the ultimate strength of pure magnesium is about 1700 psi.)

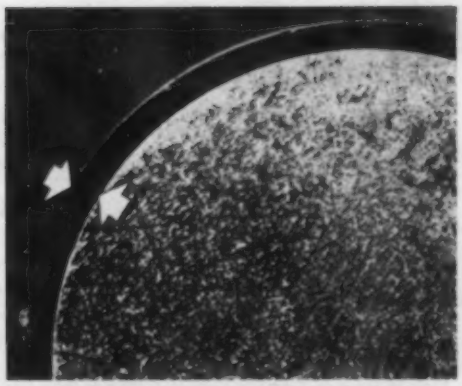
Another method of adding oxygen – by incorporating magnesium hydroxide with magnesium powder – was explored, also methods of producing fine magnesium powder by crushing in hydrocarbon liquids and by condensation of magnesium vapor in an argon stream. Extrusions of the crushed magnesium disintegrated in air with evolution of ammonia, due to the presence of 0.2% Mg_3N_2 and possibly some carbide. The spherical particles of condensed magnesium were finer, and when extruded under the same conditions as above, they give exceptionally smooth rods, completely stable in air.

A relatively cheap process of producing fine magnesium powder has been developed by Berk & Co. Ltd. Molten magnesium is atomized by a stream of kerosene or similar hydrocarbon and the resulting powder centrifuged to remove most of the oil, then compacted and extruded. Some work on beryllium compacts resulted in the production of material similar to S.A.P. in which grain growth at elevated temperatures was severely restricted by surface films apparently of iron compounds picked up during grinding operations. It would appear that such "S.A.P.-type" beryllium could find an application as fuel containers for high-temperature operation, where excessive grain growth is undesirable; it may be significant that beryllium-clad uranium samples could be heated to temperatures about 150° C. higher than those made from other types of beryllium powder before failure occurred.

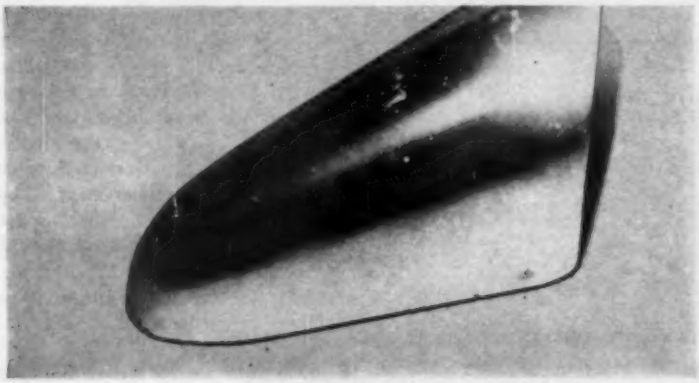
(Continued on p. 190)



UNICHROME BRIGHT CRACK-FREE CHROMIUM MADE THIS DIFFERENCE IN PROTECTION. Photographs show results of 72 hour acetic acid salt spray test. Part at top was plated with ordinary chromium according to automotive manufacturer's specifications for copper, nickel, chromium finishing. Part at bottom had same copper and nickel deposits but Unichrome Crack-Free Chromium replaced the ordinary chromium, thus greatly increasing corrosion resistance.



UNICHROME SRHS® CHROMIUM MADE THIS DIFFERENCE IN THICKNESS. Enlarged cross sections of identical steel rods show ratio of thickness of plate from ordinary chromium solution (top) to thickness from SRHS Chromium Solution (bottom) . . . a much thicker deposit in the same plating time!



How to get more corrosion resistance from chromium plate

When consumers find fault with decorative chromium plate, it's generally due to early corrosion.

This trouble starts with pores and cracks that occur in all ordinary chromium in the range of thicknesses generally used for decorative plating. Road chemicals, salt atmosphere and fumes find a path right down to base metal. Corrosion starts. As corrosion increases, finish failure progresses, allowing still more corrosion.

But you can stop this at the source.

THICKER, CRACK-FREE CHROMIUM

Chromium itself is passive. It doesn't corrode. Eliminate pores and overcome its cracking and you greatly improve its corrosion *protection*. Pores are eliminated by thicker plating. To overcome cracking, use the Unichrome Bright *Crack-Free* Chromium Process. This deposit is free from corrosion-admitting cracks. It has already been used in automotive production for a year.

MINIMIZE PRODUCTION PROBLEMS

Unichrome *Crack-Free* Chromium is far superior to ordinary chromium not only in protection, but also in operating advantages. The solution is self-regulating. It offers improved throwing power, also better coverage — even over passive nickel.

TO PLATE THICKER CHROMIUM

For those who desire thicker deposits but do not require freedom from cracking, other Unichrome self-regulating processes offer distinct advantages. They plate up to 80% faster than ordinary chromium plating processes. They cover parts with less dulling or burning, are less susceptible to clouding due to current interruption. Control is simplified by their self-regulating features.

Whichever process is best for your products, Metal & Thermit has over 30 years of service experience to help you make it work. Call in an M&T plating engineer to survey your requirements, tell you what's needed for the results you want. Or, send for Bulletins.

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Powder Metallurgy . . .

Notable work on extrusion of rounds and pressing of tubular shapes has been done, working especially with beryllium powder, but probably having much wider application.

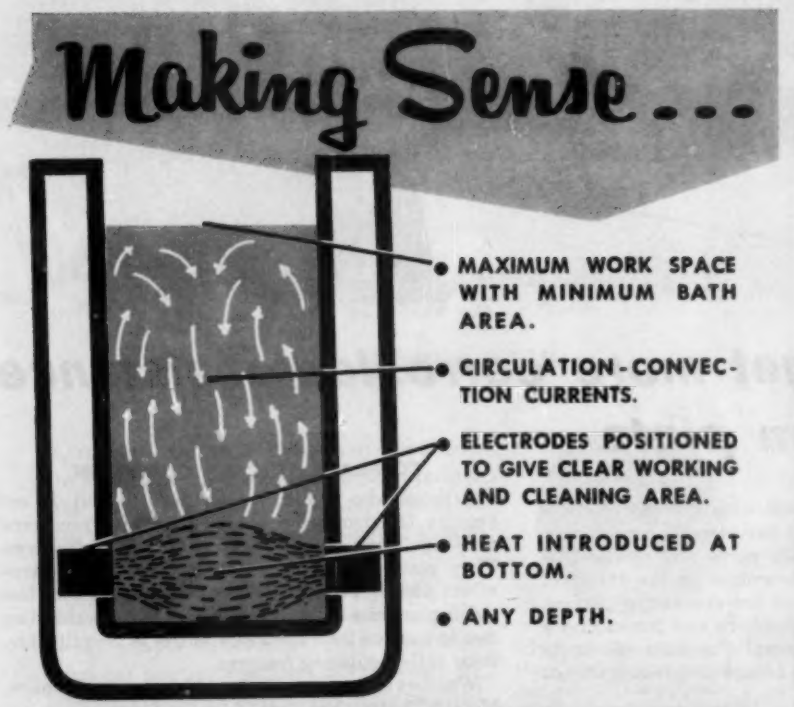
Beryllium tubes were hot compacted at about 800° C. (1475° F.) by radial compacting pressure (transmitted by molten lead in a thin-gage steel tube) applied to a concentric layer of powder inside a heated Nimonic 80 die mold fitted with a tapered split sleeve. The equipment is shown in Fig. 2 (p. 96). Concentric multilayer compacts (and hollow fuel elements) can be fabricated in the same way from several concentric powder layers.

Extending this principle of hot compacting, a high-temperature pressure chamber was designed for isotropic compacting of large numbers of sealed evacuated steel vessels containing compacts of any desired shape. Internal pressure was raised by a reciprocating ram pumping lead into the chamber which could be internally heated electrically to about 850° C. (1550° F.). The pressure chamber was itself prevented from expanding by a stout external water cooled steel vessel from which it was insulated by relatively incompressible thermal insulation.

Various plastic materials were used to make deformable containers for the powder mass in a more general investigation of the possibilities of forming fuel elements in complicated shapes by isotropic compacting. For cold compacting, a rubber-like composition proved most satisfactory. It could be melted and cast into cylindrical steel compacting dies in a form having suitable cavities for the powder mass, so that uniform isotropic pressure could be applied to the latter by the simple application of axial pressure to the plastic. In this way even hollow shapes of complicated contour, such as those with external fins, could be compacted by causing the plastic to apply uniform pressure both inside and outside the powder mass. The same principle was applied to hot compacting at about 800° C. (1475° F.) by using copper as the pressure-transmitting medium, either in a Nimonic alloy die mold or in a deformable frame.

The principle of the deformable frame is shown in Fig. 3. The die pressure allowable is proportional to the coefficient of friction between die and frame, the shear strength of the latter, and to its dimensions. In hot pressing at 1000° C. (1825° F.) using a Nimonic 100 frame (yield stress about 9000 psi. at 1000° C.) and $t = 5$ h, a pressure on the order of 90,000 psi. was sustained. Higher pressures would be possible with stronger compression plates.

Sheath Extrusion – Considerable work has been done on the extrusion or forging of powder into a coherent mass, the powder being contained in a tight can, evacuated before heating. For example, the finer thorium powder (reduced without flux with calcium chips) has been fabricated into high-density tubes and rods by sheath extrusion at 750° C. (1400° F.) in a copper cannister, or at 950° C. (1750° F.) in a steel cannister. The former was satisfactory; at the higher temperatures, the steel is very soft and the can frequently broke. A vacuum or protective atmosphere was necessary in the can to avoid oxidation and nitridation of the thorium.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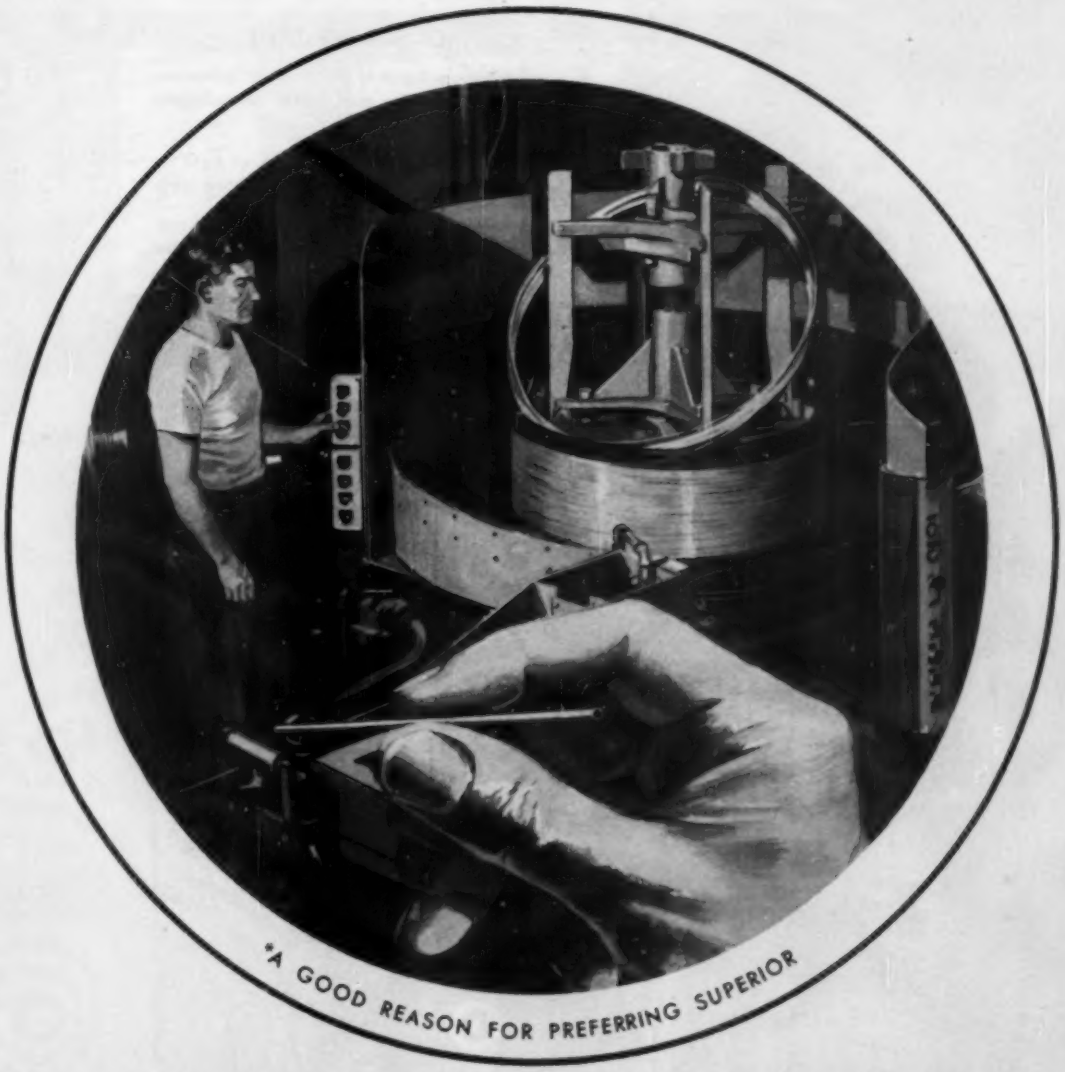

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D. A one-stage magnetic amplifier amplifies small current from the photocell in the measuring unit. This is the only active electronic element in the controller.

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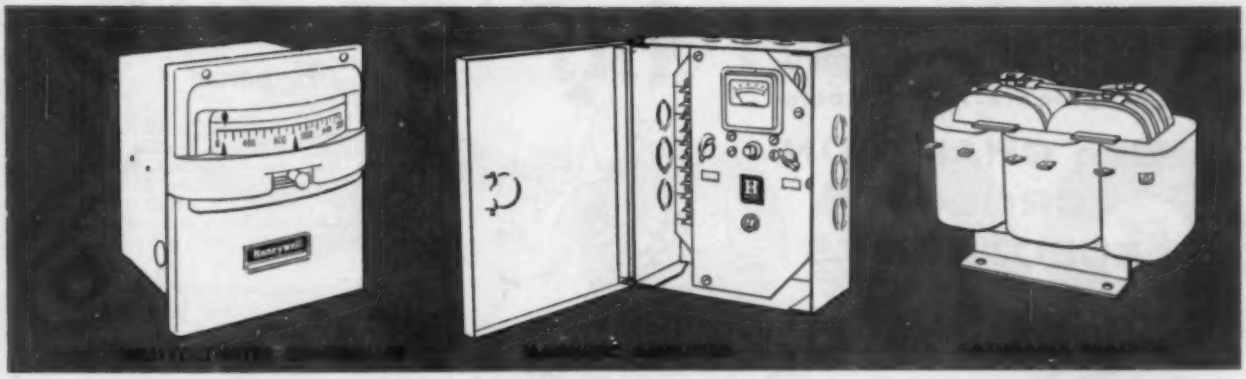
Pyr-O-Volt **controller is dependable and trouble-free. Built-in voltage regulator maintains voltage within ±1% of level required for maximum operating stability. Thermocouple burnout protection is optional. Spare operating lamp is supplied with all instruments. Available in both horizontal and vertical case models.**



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Use this dependable, low-cost *Pyr-O-Volt** controller

- **No tubes to wear out**
- **Voltage regulation**
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- **Contactless, stepless control**

Here's a low-cost instrument for reliable stepless control of saturable reactors, r.f. generators and other power amplifiers. It has a proportional band adjustable from 3/8% to 5%, and a manual reset adjustment which shifts the control point over 100% of the proportional band.

You can use this proportional output millivoltmeter-controller with the General Electric *Reactrol***, and the Westinghouse *Furnatron*.*** Combined with a Brown magnetic amplifier, it can control saturable core reactors up to 100 kva. Complete packaged systems available.

Contact your nearby Honeywell field engineer for complete details. He's as near as your phone.

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Use CHAMPION CROLOY® ELECTRODES

For top drawer welding of Chrome Moly Steels, **Champion Croloy Electrodes** have excellent handling characteristics in all positions, and produce radiographically clean welds of unsurpassed mechanical properties. **Champion Croloy Electrodes** are available in all of the popular grades from 1¼% Chrome, ½% Moly to 9% Chrome 1% Moly in 3/32" through 5/16" diameter. Only Croloy Electrodes are identified with the Croloy imprint on each Electrode and are manufactured under U.S. patent license.

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Calcium Reduction of Zirconium

Digest of "Preparation of Zirconium and Hafnium Metals by Bomb Reduction of Their Fluorides", by O. N. Carlson, F. A. Schmidt and H. A. Wilhelm, *Journal*, Electrochemical Society, Vol. 104, January 1957, p. 51-56.

THIS PAPER contains a very detailed description of a new process for the preparation of zirconium and hafnium metals. In this process, the metals are obtained in massive form as zinc alloys and the zinc is distilled out at high temperature under vacuum. The zirconium-zinc and hafnium-zinc alloys are produced in a sealed bomb by reaction of the tetrafluoride of either zirconium or hafnium with calcium in the presence of zinc.

In the production of zirconium, the first step is to prepare a high-purity fluoride exempt of oxygen. The conversion of hydrated zirconium oxychloride into the fluoride is described in great detail, and the authors insist on the fact that the success of this method largely depends on very close control of all the variables. The total metallic impurity content of the zirconium fluoride is less than 0.05%, half of this value being the sum of silicon, chromium, magnesium, nickel, copper, iron and calcium, and the other half being titanium. The equipment which was built for the preparation of the fluoride was relatively large and could be considered as a pilot plant, since more than several hundred pounds of fluoride were prepared.

Reduction of the zirconium tetrafluoride is carried out in a steel bomb, the charge consisting of calcium and zinc. A small amount of iodine is also added to increase the amount of heat generated during the reaction. The amount of zinc required is calculated so that the zirconium-zinc alloy is near a eutectic composition containing about 33% Zn and melting around 1000° C. (1830° F.). A refractory liner must be used in the steel bomb. MgO and ZrO_2 reacted with the molten zirconium-zinc alloy and a prohibitive amount of oxygen was introduced into the zirconium metal. Calcium oxide appeared to be a satisfactory liner in some tests, but

WHO BUYS DIE CASTINGS?

These Industries Do!

Last year, die casting accounted for the largest single use of zinc — displacing galvanizing for the first time in history as the metal's major consumer.

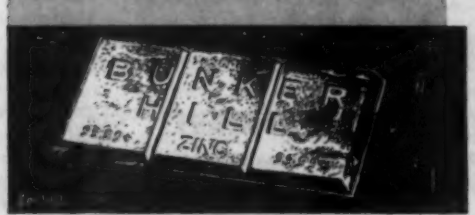
Consumption of zinc for die casting in 1957 is estimated at 370,177 tons. This amounts to 40% of all slab zinc consumed last year. Shipments of zinc die castings by job shop, or custom producers represented some 61% of the zinc die casting metal consumption totals. The balance represents captive production by end product manufacturers.

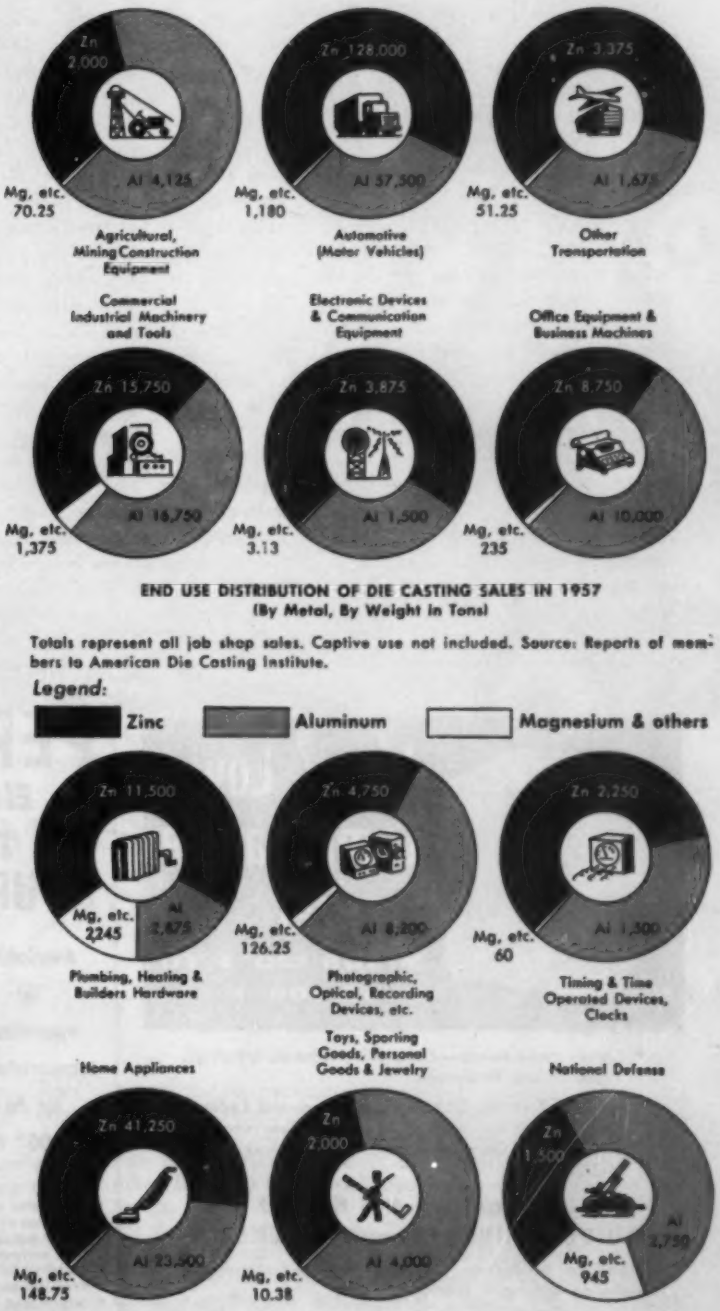
Prior to 1928, the year Bunker Hill pioneered the production of "four-nines" metal, die casters would never have dreamed that their zinc-base products would become a vital factor in modern engineering processing. Least of all could they have foreseen that in a relatively short span of years their infant industry would outrank the galvanizing industry as the nation's largest consumer of zinc.

DIE CASTING
Is the Process

ZINC,
the Metal

BUNKER HILL,
THE PREFERRED ZINC





END USE DISTRIBUTION OF DIE CASTING SALES IN 1957
(By Metal, By Weight in Tons)

Totals represent all job shop sales. Captive use not included. Source: Reports of members to American Die Casting Institute.

Legend:
Zinc — Aluminum — Magnesium & others

BUNKER HILL 99.99+% ZINC

EASTERN SALES AGENTS
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SALES OFFICE FOR PACIFIC COAST
THE BUNKER HILL CO., 660 MARKET ST., SAN FRANCISCO, CALIF.

Calcium Reduction . . .

the results were inconsistent. Calcium fluoride was adopted as the best liner material.

The massive zirconium-zinc alloy obtained in the steel bomb is then heated in vacuum to remove the zinc. The rate of heating must be small because a large volume change takes place. About 95% of the zinc can be removed by heating to 1250° C. (2280° F.), but temperatures between 1500 and 1600° C. (2730 and 2910° F.) are necessary to bring the zinc content down to 0.05%. Since this operation is carried out in a graphite crucible, some carbon diffuses into the zirconium. This can be avoided by lining the crucible with a zirconium sheet.

The physical properties of the zirconium obtained by calcium reduction compare favorably with those of the metal obtained by the conventional Kroll process. After melting in a graphite crucible or in an inert arc furnace, the hardness is between Brinell 120 and 135 and the ingot can be cold rolled to 10 mil sheets, with intermediate annealings. A typical analysis of calcium-reduced zirconium is: 0.07% total metallic impurities, 0.03% C. No vacuum fusion analysis of oxygen was performed, but the authors estimate the oxygen content to be about 0.1% on the basis of hardness data and lattice parameter measurements.

There is very little difference between the production of hafnium and that of zirconium. Hydrated hafnium oxychloride is first transformed into the tetrafluoride. The zinc addition into the reaction chamber is such that the final hafnium-zinc alloy contains about 21% Zn. The removal of zinc from this alloy is also carried out in vacuum, but at a higher temperature than for zirconium (1800 instead of 1600° C.). The hafnium produced contains less than 0.06% of combined metallic impurities (0.07% C and 0.05% N). Oxygen content was not determined but the fact that the ingot could not be cold rolled without cracking indicates that the oxygen concentration was high.

In reading this most interesting paper, one has the impression that the calcium reduction method could be considered for industrial production of zirconium. There is no attempt made in this paper, however, to discuss the advantages and disadvantages of this method and compare it with the conventional Kroll process. Whether or not the calcium-zinc reduction method will ever be considered for large scale production is probably a question of economics. POL DUWEZ

PRINCIPLES OF HEAT TREATMENT

Probably the most widely used discussion of activity in the steel processing and fabricating field. Each chapter is preceded by a summary of its contents for easier reading and understanding. M. A. Grossmann—303 pages—6x9—illustrated — cloth — $6.00. *Clip and send to Technical and Engineering Book Information Service, 7301 Euclid Avenue, Cleveland 3, Ohio.*

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Standard production model, (white) self-contained, including automatic controls.

34" high—28" deep—38" wide—outside dimensions.

Complies with National B-9 Refrigeration Code.

New low price—immediate delivery (available without automatic controls, for Dry Ice Storage).

Alpha Electric Refrigeration Co.

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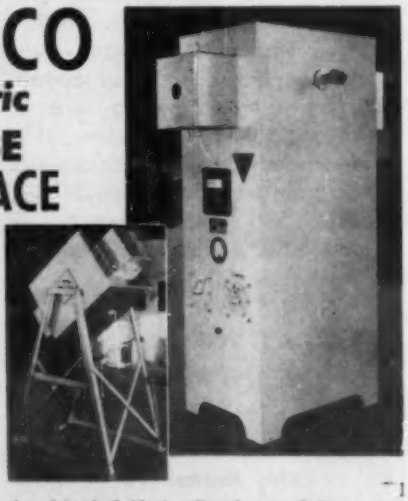

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Long Manufacturing Division— Borg-Warner Corporation

The story of Wissco Belts is best told by their users. For instance, Mr. Henry Colenso, Plant Engineer of the Long Manufacturing Division, Detroit, Michigan says:

"Our Wissco Belt has enabled us to increase our production almost 4% by eliminating downtime due to belt replacement and slack take-up."

The belt carries oil coolers through a brazing furnace operating at a temperature of 2090°F . . . then runs through a water jacket which cools the belt to room temperature.

"The thicker belts we used previously could not stand the stress caused by these sudden large temperature changes," Mr. Colenso reports. "They would stretch so that the conveyor had to be stopped for about three hours every week while two or three feet of slack were cut out and repairs made. And we lost a full day's production on this portion of the line once every four months, while the belt was completely replaced. Our total annual loss due to these stoppages alone amounted to almost 4% of our overall production.

"Since our Wissco Belt was installed about six months ago, we have not had one single belt breakdown. The main reason for its continued successful operation is its thin, flat spiral construction," Mr. Colenso continues. "The spirals in the belt are preseated during manufacture, and the belt has not stretched during operation. Compared with other belts we have used, and we've made many experiments, the Wissco Belt has proven outstanding for long life and continuous service."

What Wissco Belts have done for Long Manufacturing, they can do for you in your processing-conveying operations. For further information contact the sales office nearest you.

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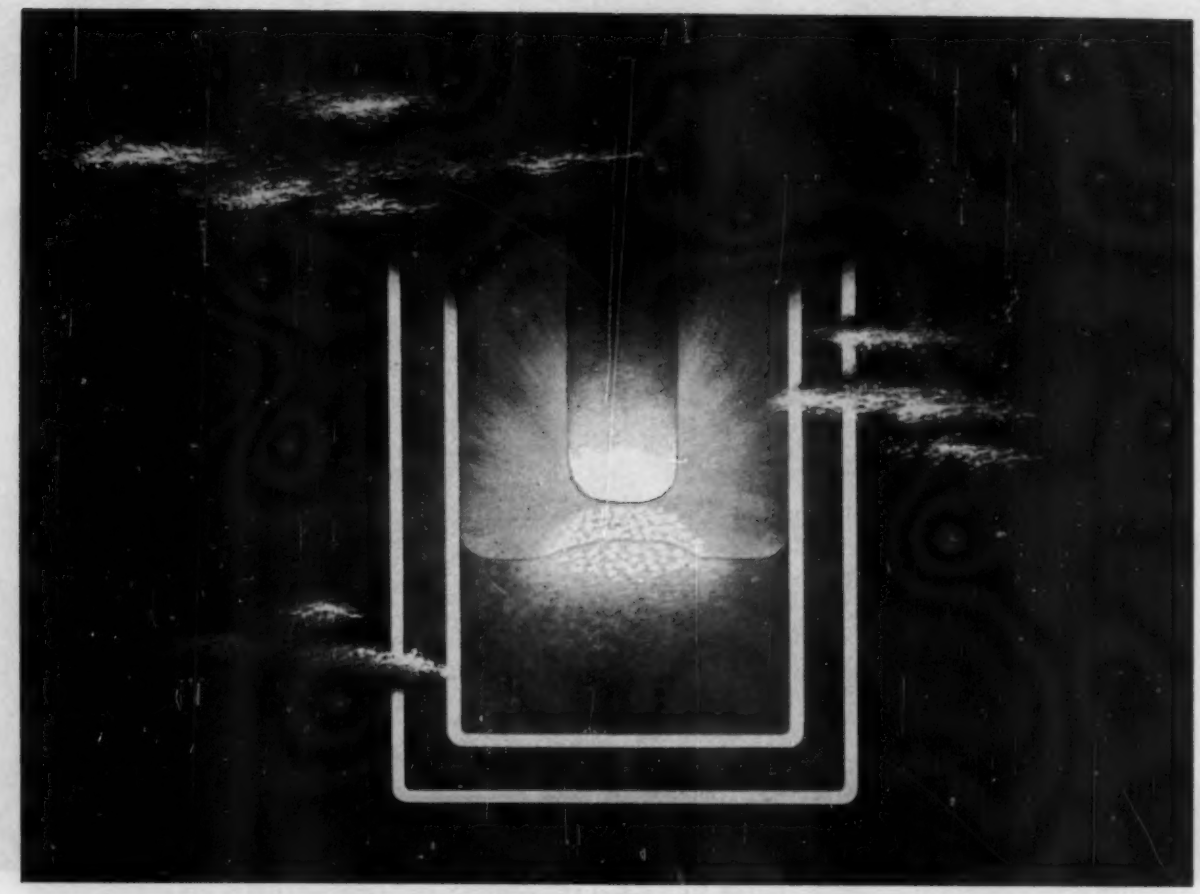

The role of Sylvania consumable electrodes in arc-cast

Metals of the Future

EXCITING and important applications await the development of new high-temperature alloys. Many of these, already in advanced stages of development, are being arc-cast from consumable electrodes.

Working hand in hand with the metal industry, Sylvania has applied its knowledge of powder metallurgy to supply the vital consumable electrode.

Special alloys as well as pure Molybdenum, Tungsten, Nickel, Copper, Chromium, Titanium, and Tantalum have been isostatically pressed and sintered in a wide range of sizes. Emphasis has been placed on "evaluation" sizes down to ½" in diameter, tailored to specific experiments.

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sure it's big

. . . but not particularly big or unusual

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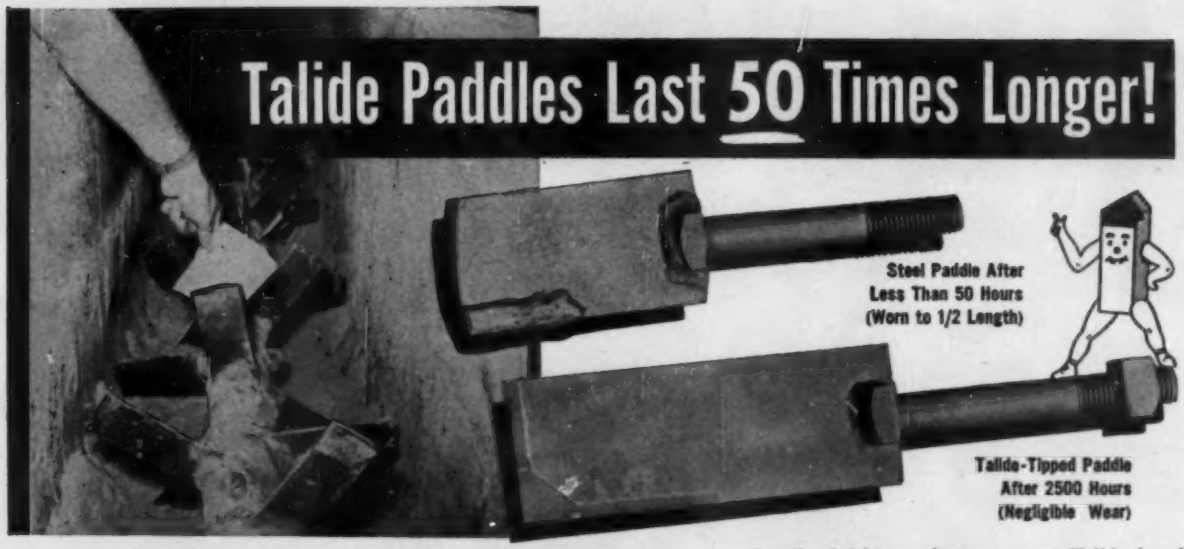
Talide Paddles Last 50 Times Longer!



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- **FRICTIONAL RESISTANCE**— Lower than steel, non-galling, "slippery" properties higher.

ALL TALIDE METAL grades are made in latest type vacuum electric furnaces by precision methods under rigid control. A wide variety of shapes and sizes can be supplied—up to 25" in diameter, 100" in length, and 5000 pounds by weight. Parts can be supplied to any grit finish required down to one micro-inch. The physical properties of the most commonly used grades are listed below. Other grades are available for specialized applications.

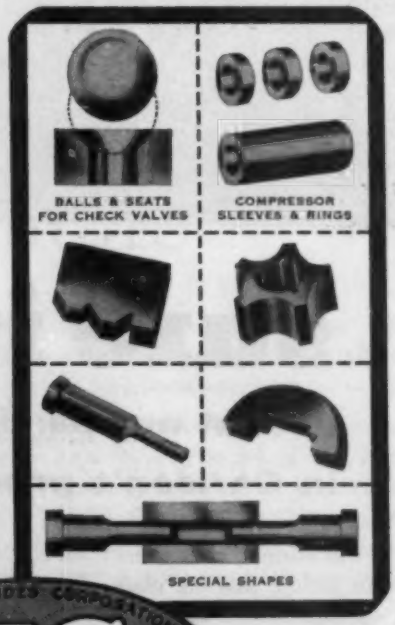
PHYSICAL PROPERTIES OF TALIDE METAL (P. S. I.)

Application	Operation	Talide Grade	Rockwell "A" Hardness	Specific Gravity (Density)	Transverse Rupture Strength	Compressive Strength	Co-Efficient of Thermal Expansion	Modulus of Elasticity (Deflection)
WEAR SURFACE	No Shock	C-91	91.8	14.90	235,000	710,000	3.00x10-6	91,000,000
	Light Shock	C-89	91.0	14.75	265,000	670,000	3.65x10-6	84,000,000
	Medium Shock	C-88	89.5	14.55	295,000	635,000	4.00x10-6	80,000,000
IMPACT	Light	C-85	88.4	14.25	315,000	600,000	3.75x10-6	77,000,000
	Medium	C-80	87.0	13.85	335,000	550,000	4.50x10-6	74,000,000
	Heavy	C-75	85.0	13.15	355,000	500,000	5.00x10-6	70,000,000

Note: Hardness values may vary plus or minus .2 to .3 on individual lots.

Leading brick manufacturer reports Talide-tipped pug mill paddles have outlasted 50 sets of hard-faced steel paddles to date—and are still in use. Operation involves mixing abrasive ceramic, clay and brick compositions.

TALIDE METAL is saving industry millions of dollars annually by wear-proofing vital parts on machine tools, presses, pumps, compressors and other types of processing equipment used in the steel, oil, chemical, plastic, auto, rubber, textile, glass, ceramic, mining and metalworking industry.



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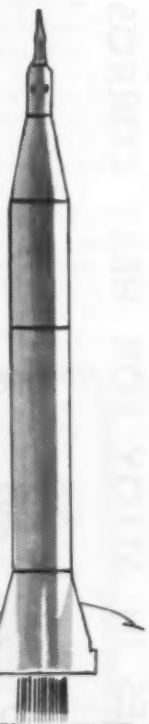

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MOLY NEWS
CLIMAX MOLYBDENUM • DIVISION OF AMERICAN METAL CLIMAX, INC.

Climax Develops an Extremely Tough, Abrasion-resistant Chrome-Moly White Iron

New Alloy Proves Superior in Erosive Applications

A new martensitic white iron has proved exceptionally tough and resistant to abrasion. It's called Alloy 42. Its excellent combination of properties are related to its structure — which consists of hard chrome-moly carbides favorably distributed in a matrix of martensite plus retained austenite.

Tests indicate Alloy 42 is especially economical for parts subject to erosive wear: sand pumps, flotation impellers, sand classifier wear shoes, pug mill blades, brick mold liners and chute liners.

For example, heat-treated Alloy 42 impellers in a 5" sand pump handling coarsely ground taconite ore have already lasted over 1,000 hours. Previous impellers made of a 4.5% Ni, 1.5% Cr type of martensitic iron lasted only 350 to 400 hours.

Because of its toughness, Alloy 42 can also be used where moderate impacts would cause low alloy types of white iron to break or spall. And it may prove more economical than the soft rubber parts or linings now used in various abrasive applications. Its resistance to tearing by tramp coarse materials and chemical attacks by oils and other organic compounds is an obvious advantage.

The recommended composition range is: Carbon 3.00-3.50%; Silicon 0.30-0.60; Manganese 0.60-0.90; Chromium 15.0-18.0; Molybdenum 2.75-3.25.

A Climax bulletin on Alloy 42 discusses melting and casting, molds and shrinkage, heat treatment, structure, physical properties, machinability, welding and cutting. *For a free copy, circle #1 on the coupon.*

Heat Treating Improves the Wear Resistance of Gray Iron

Heat treating can improve many of the properties of gray iron, particularly resistance to wear. Wear resistance in quenched-and-tempered gray iron is many times greater than that of pearlitic irons. With cams and similar parts, hot quenching provides better wear resistance than quenching and hardening to the same hardness. Surface hardening is frequently selected for gray iron because it locally improves wear resistance with minimum distortion.

Why Moly Iron Bulletin #6 contains valuable information on surface hardening, annealing and stress-relieving molybdenum-alloyed irons. This bulletin gives examples of improvements obtained by heat treating gears, cable drums, pump-ring castings, tappets, valve guides and machine tool ways.

Flame hardening the teeth on a sprocket improves wear resistance with minimum distortion.

For a free copy of "Why Moly Iron Bulletin #6," circle #2 on the coupon.

Tempering Low-Alloy Creep-Resistant Steels

A recent British paper discusses the roles of chromium, molybdenum and vanadium in low-alloy steels with high creep strength. The relation between creep properties, microstructure changes and carbide composition is given special attention.

For a copy of "The Tempering of Low-alloy Creep-resistant Steels Containing Chromium, Molybdenum and Vanadium" by E. Smith and J. Nutting, circle #6.

Moly Helps High Alloys Fight Corrosive Attacks

Highly alloyed materials are playing a greater part in combating corrosion. A current paper on these alloys considers the molybdenum-bearing alloys at length and also discusses cobalt-base alloys and silicon-bearing alloys.

For copies of this paper, "High Alloys to Combat Corrosion" by E. D. Weisert, circle #7.

Thermenol Shows Excellent Resistance to Heat, Corrosion

Thermenol, an iron-aluminum-molybdenum magnetic alloy, compares favorably with other high-temperature materials, and in some cases promises even better service. For unlike many alloys, it doesn't lose tensile strength rapidly up to 1200 F. It also has excellent resistance to oxidizing and sulfur-bearing atmospheres at high temperatures.

For a copy of "Iron-aluminum Magnetic Alloy Has Excellent Heat Resistance," circle #8.

Moly in Nickel-base Casting Alloys Improves High Temperature Service

Molybdenum is helping at least two nickel-base alloys to work more effectively in high temperature applications. One of the alloys, with 5% Mo, combines good castability with very good creep strength at temperatures up to 1800 F (much better than that of moly-free alloys). The second, with 10% Mo, shows high resistance to thermal shock.

For free copies of "Some Properties of Nickel-base Casting Alloys for High-temperature Service" by D. R. Wood and J. F. Gregg, circle #3.

Cast Steels Studied at Low Temperatures

The British Steel Castings Research Association has completed new studies on the effect of melting practice, composition and treatment of steel castings. Five of the seven alloy steels investigated contained molybdenum. The benefits of using molybdenum in low alloy steel castings for low temperature service are clearly shown in comparisons of 1.5% Mn and 1.5% Mn-Mo.

For reprints of "The Low-temperature Impact Properties of Cast Steel" by W. J. Jackson and G. M. Michie, circle #4.

New Data Available on Low Carbon Bainitic Steels

Studies have been made on new steels based on boron-0.5% Mo. Tensile strengths up to 180,000 psi can now be obtained within the bainitic range with a wide range of cooling rates. Thus these low-carbon bainitic steels offer a good combination of mechanical properties as-rolled or as-air-cooled. These properties can be obtained in large sections because hardenability is high. Good welding properties and tempering characteristics make the steels especially suitable as high-strength weldable steels, forgings, die blocks, etc.

For copies of "Low-carbon Bainitic Steels" by K. J. Irvine and F. B. Pickering, circle #5.

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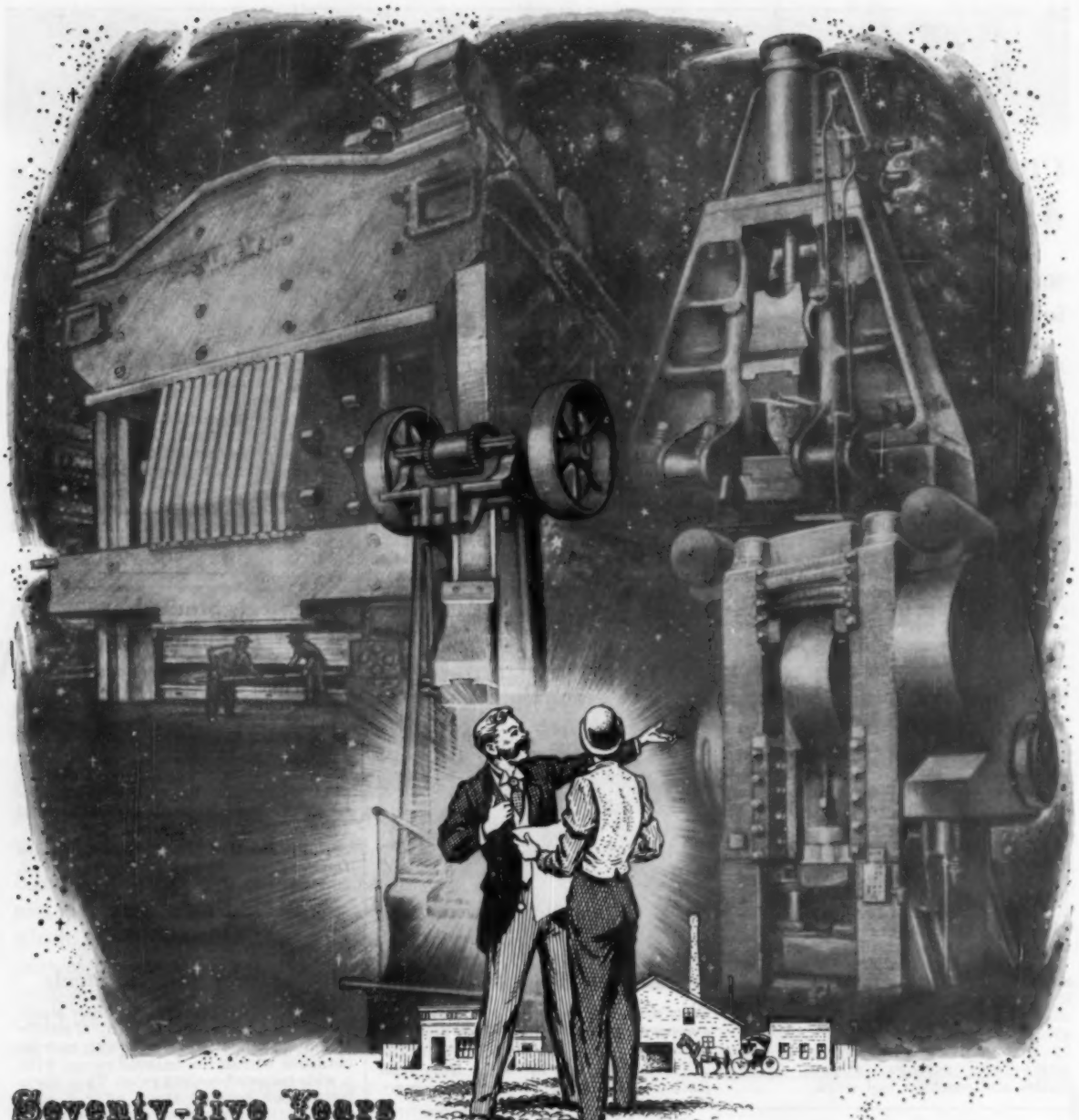

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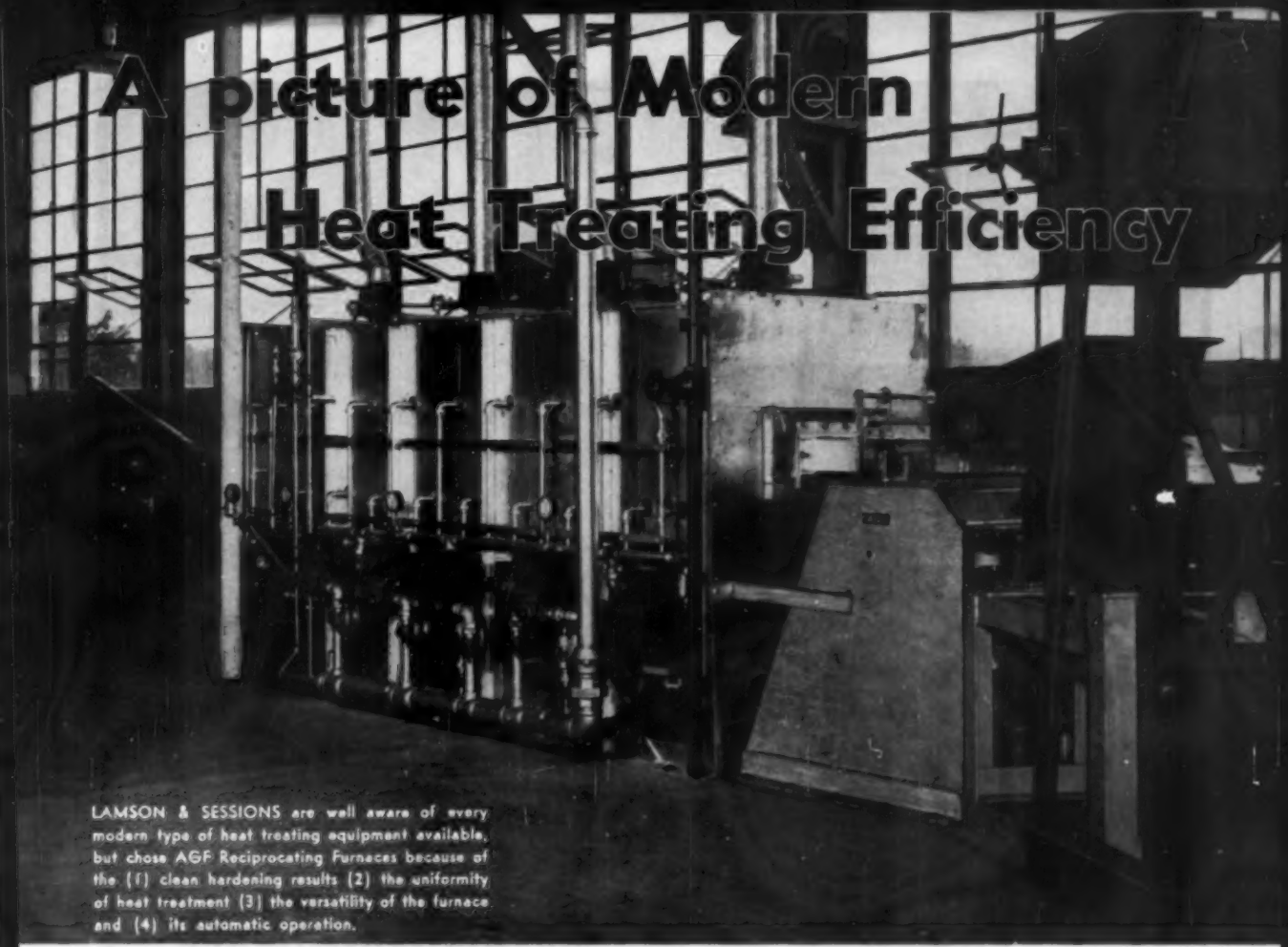

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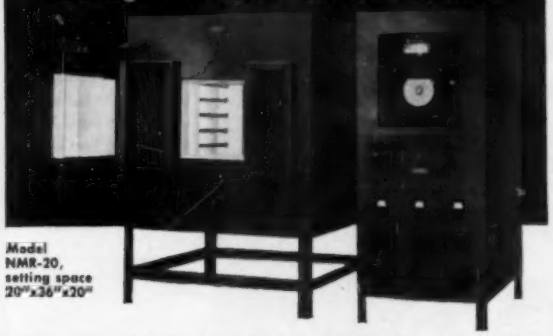

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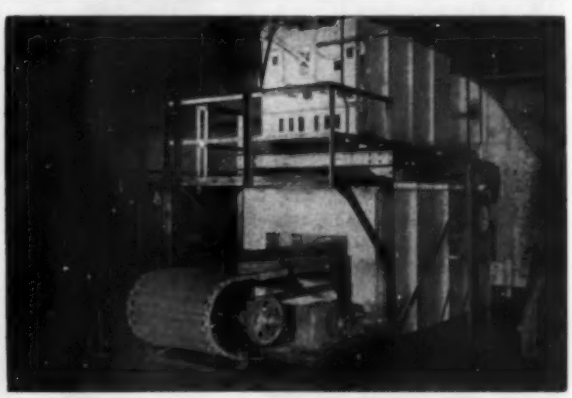

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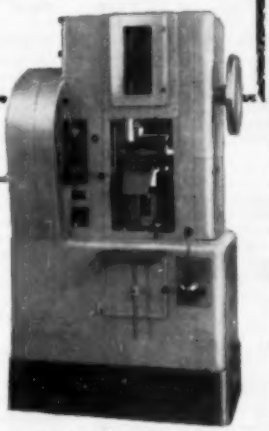

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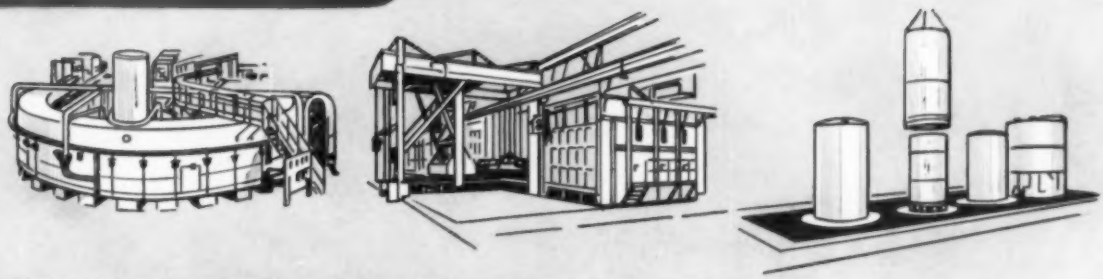

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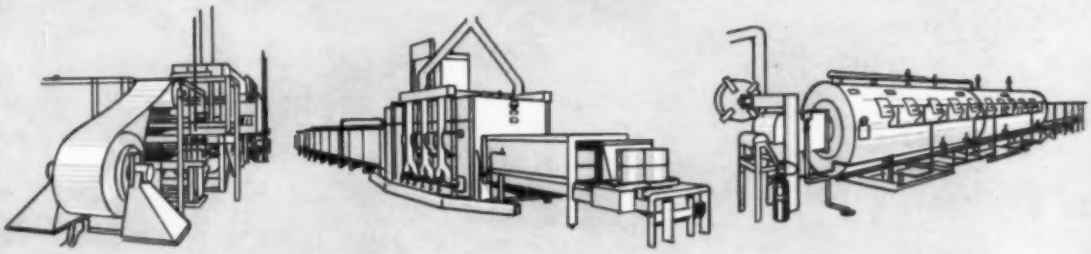

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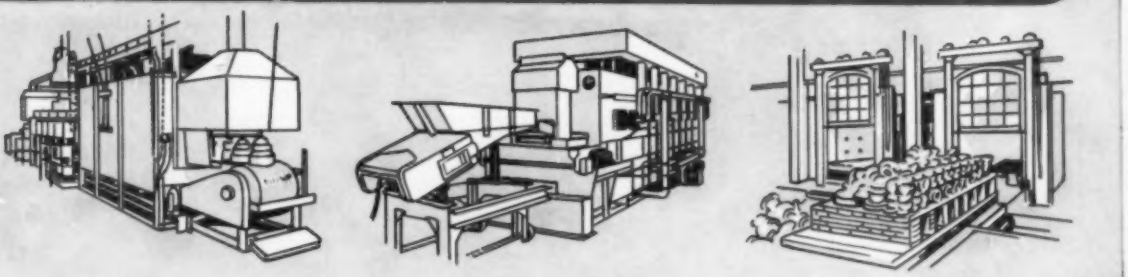

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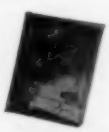

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